ELECTRICAL ENGINEERING

ULY 1944

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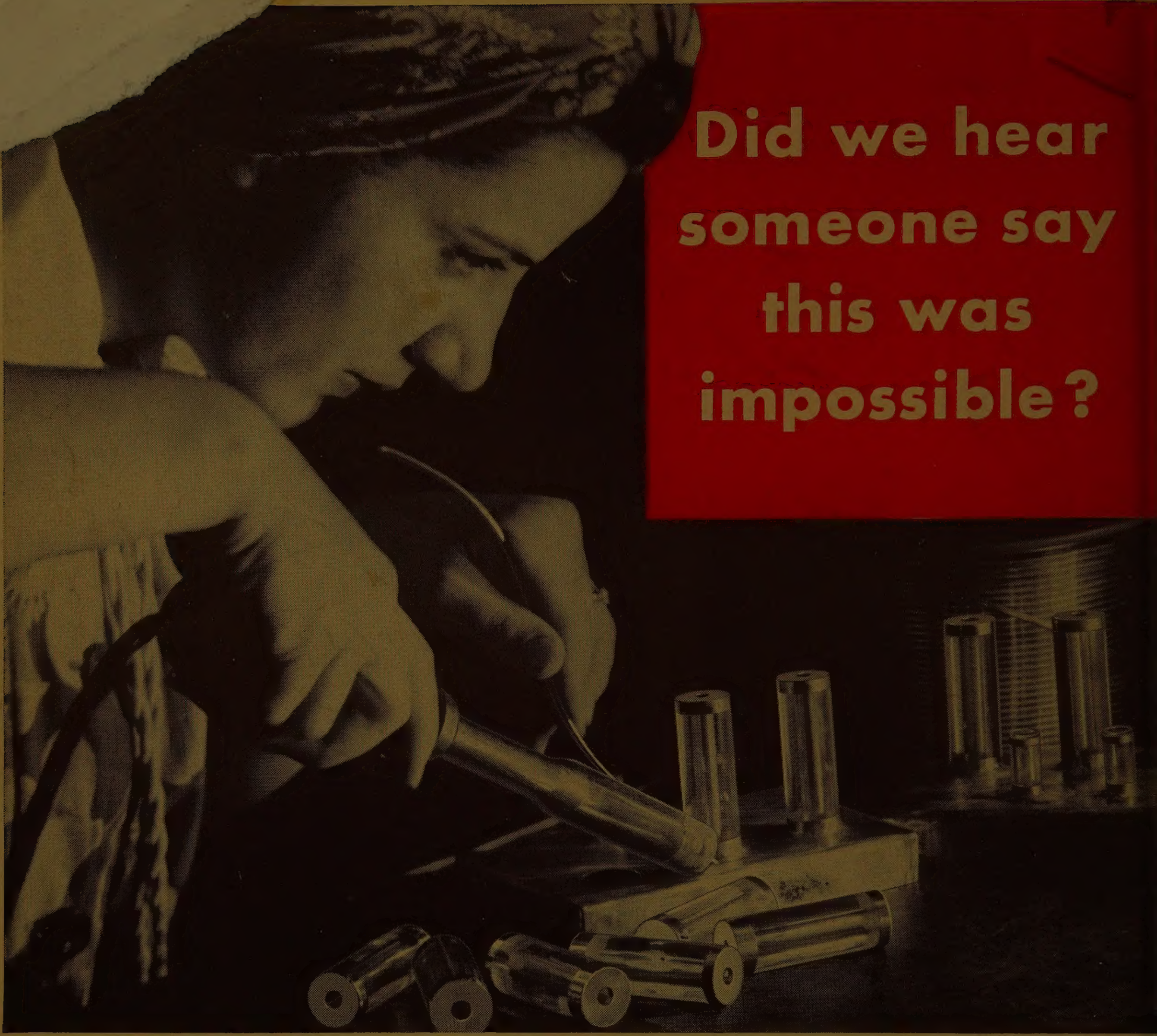
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The Cover: A mobile steam power plant of 3,750-kva capacity, one of a number of such units being constructed in the United States for shipment to war-devastated areas.

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Fluorescence Aids Mining

H. T. PLUMB
FELLOW AIEE

Ultraviolet light and fluorescence are useful aids in the mining industry. This engineer describes their general uses and limitations, and explains the theory of fluorescence in simple terms without resort to complicated mathematical or physical details.

FLUORESCENCE is a smart way of saying "fluorspar luminescence." Ninety years ago the great mathematical scientist, George Gabriel Stokes, was doing a chemical experiment with fluorite, when accidentally the rock came into view of an arc lamp. Stokes noticed the color of the crystals change suddenly from green to blue. His keen mind went to work on that trivial observation.

Fortunately he was not only a smart physicist and chemist, but a brilliant mathematician. For many years he studied this experiment and eventually evolved Stokes' law of fluorescence. He found that fluorescent light is emitted at a lower frequency and longer wave length than the exciting light; hence fluorescent colors, to be visible, usually require excitation from an invisible light of higher frequency, such as ultraviolet, cathode rays, or X rays. Blue or violet visible light may cause green, yellow, or red fluorescence, or may even produce fluorescent infrared rays which are invisible.

THEORY

Fluorescence, or photoluminescence by exposure to invisible radiations, is entirely different from colors seen by ordinary light reflection or transmission. Reflected light has the color or frequency that was in the original light, just as an echo of sound has the same pitch as the original sound waves. Fluorescent color is independent of the surface color caused by ordinary visible light. The phenomenon may be due to atomic resonance or "sympathetic vibration" of electrons within the molecules.

Fluorescence depends on the chemical or atomic molecular structure of the material which fluoresces. Each atom has electrons revolving in certain orbits or potential levels. The outer electrons may be elevated to other orbits normally vacant. There are potential levels about the nucleus of every atom much like gravitational levels about the earth, or like planetary orbits about the sun. If the electrons within an atom are arranged so that one of these can vibrate freely at a certain higher frequency, then by resonance it may absorb energy from a high-frequency exciting light source and temporarily revolve in an orbit with higher energy. When it falls back to its normal orbit, the extra energy which it received will be reradiated as light, but of a lower frequency or different color from the exciting ray.

Stated again in a different way, when a quantum bullet (energy photon) of high-frequency light collides with an electron vibrating peacefully in its normal place, the electron may be knocked to some other level farther from the nucleus of the atom. Whenever the electron falls back to its normal level, the increased energy which it received from the photon is reradiated as light, but generally at a lower frequency than the original light beam Apparently the electron cannot absorb all the energy of the photon; otherwise the reradiated energy would have the same color.

The reradiated energy is the difference in total energy between the atom or molecule which is excited and that which is not excited. The amount of this energy is directly proportional to the frequency or color of the reradiated light. A scientist named Planck wrote the law thus:

$$E=E_{ex}-E_n=hf$$

where E is the reradiated energy, E_n is the normal energy of the atom, E_{ex} is the total energy of the atom when excited to the higher level, h is Planck's constant, and f is the frequency of the reradiated light.

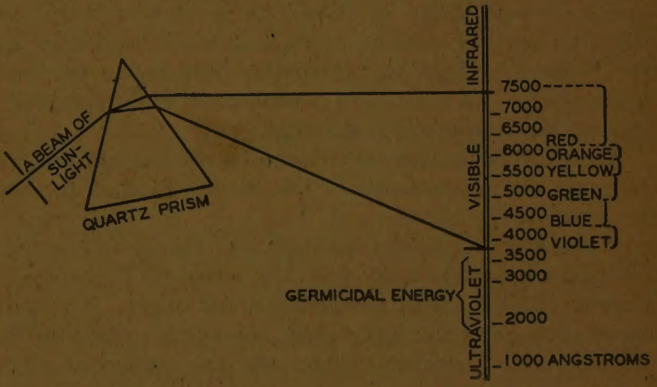

Figure 1. Schematic diagram of sunlight spectrum, showing the range of wave lengths of infrared, visible light, and ultraviolet energy

If the displacement is instantaneous only and ceases immediately with the excitation, the phenomenon is called fluorescence. If the displaced electrons do not all immediately return to their normal places, but do so gradually, the emission is called phosphorescence. The displaced electron may fall back in a single movement or

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H. T. Plumb is a consulting engineer, Salt Lake City, Utah.

Essential substance of a paper presented at the AIEE national technical meeting, Salt Lake City, Utah, September 3, 1943.

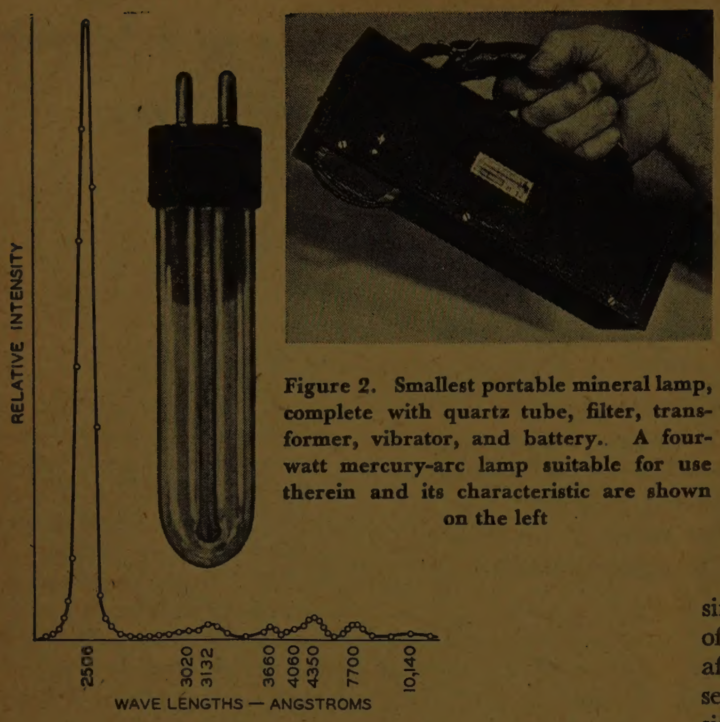

Figure 2. Smallest portable mineral lamp, complete with quartz tube, filter, transformer, vibrator, and battery. A four-watt mercury-arc lamp suitable for use therein and its characteristic are shown on the left

hesitate at an intermediate level. A baseball batted high into the air will give a rough illustration of this. The ball is pushed to a higher gravitational level above the earth by energy from the bat. It does not stay at the new level but falls to its original level. Not all of the energy received from the bat is returned to the catcher's hands; some is lost enroute. Losses may lower exciting energy so that the energy is reradiated at a lower frequency.

The returning ball may be held for a time in the top of a tree, or at some intermediate level. This temporary delay may help us understand phosphorescence. The phosphorescent delay in crystalline substances is due to slight amounts of metallic impurities which, imbedded in the "crystal lattice," act in similar capacity to the tree limbs above. All substances phosphoresce slightly, crystals more so than amorphous material.

There are other and more confusing mathematical ways of explaining fluorescence. For simplicity and brevity these are omitted here.

When a photon bullet has sufficient energy to force an electron completely away from the atom, no fluorescence occurs. This is called the photoelectric effect. The material containing the incomplete atom is left temporarily with a positive electric charge, and the wandering electron will bring a negative charge to whatever it contacts.

We have been explaining this theory as though there was only one bullet hitting one electron. Actually the ultraviolet source is pouring out a barrage of bullets at various frequencies. Some of the lower-frequency shots may be effective; some of the higher-frequency shots may be effective; but the most effective results will come from a certain definite frequency. Each material will fluoresce best for one certain frequency of incident light. Increasing or decreasing the incident wave length tends slightly to increase or decrease the fluorescent wave length. But this frequency relationship is not a simple fixed numerical ratio such as octave or harmonic. Every substance has its own arrangement of molecules, atoms, and electrons, and, therefore, its distinct tone or response frequency, much as each string in a piano is tuned differently and will resound to a different frequency.

The fluorescent response of a material may be a single frequency or color, or a mixture of several bands of color, or a continuous spectrum of all visible colors affecting the eye as white light. The eye averages all its sensations into one composite color. Spectographic analysis would give separate information with each line in the fluorescent spectrum.

It is well to remember that the human eye is a very limited detector of light. The best eye can see only one octave of color while sunlight contains many octaves. This indicates how color-blind we really are. Substitute photelectric eyes with high-power amplifiers in place of the human eye and the vast range of fluorescent colors with which to detect an infinite variety of chemical combinations becomes apparent.

It is interesting and important to tabulate the wave lengths and vibration frequencies of various colors and radiations. A few of these are given in Table I. The limits stated are approximate but close.

CHEMICAL ANALYSIS BY FLUORESCENCE

Analyzing rocks, minerals, and chemicals by fluorescence is not yet an exact science, or rather it is too complicated a mathematical study for beginners. Very slight amounts of chemical impurities may permit or prevent fluorescence, or may change entirely the color emitted. Similarity of color does not guarantee the same chemical content; important determinations should be checked by chemical assays. Temperature effects fluorescence and phosphorescence. Pure metals seldom fluoresce; organic materials usually fluoresce.

TYPE OF LAMP

Now as to the type of lamp best suited to the work in hand. Enormous quantities of ultraviolet light, which may

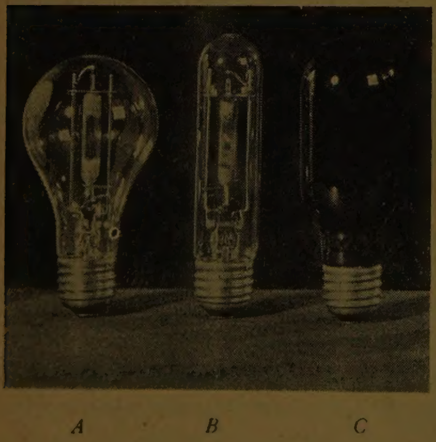

Figure 3 (left). High-pressure 100-watt mercury-arc lamps for laboratory and home use

A. S-4 sunlamp, with Corex glass outer globe
B. AH-4, with plain glass outer globe
C. BH-4, with ultraviolet filter globe

Figure 4 (right). Viewing box for daytime examination in the field making use of a portable lamp

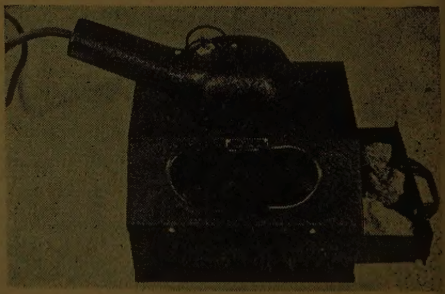

Table I. Electromagnetic Waves

	Frequency (Trillions of Cycles Per Second) (10^{12})	Wave Lengths	
		Angstroms (A)	Microns (μ)
Infrared rays			
Longest wave	1	3,000,000	300.
Shortest wave	400	7,500	0.75
Visible light			
Red	400	7,500	0.75
Violet	750	4,000	0.40
Ultraviolet rays			
"Near ultraviolet"	750	4,000	0.4
to	1,000	3,000	0.3
"Middle ultraviolet"	1,000	3,000	0.3
to	1,500	2,000	0.2
"Far ultraviolet"	1,500	2,000	0.2
to	3,000	1,000	0.1
X rays			
Longest wave	3,000	1,000	0.1
Shortest wave	30,000,000	0.1	0.00001

excite fluorescence, reach the earth's outer atmosphere. But air is a poor conductor of high-frequency light, and therefore, at the earth's surface sunlight contains very little short-wave ultraviolet. The author has a portable daylight device for examining specimens in the field. It works well for materials which fluoresce with low frequency ultraviolet. Fortunately, men have learned how to build arc lamps which produce an abundance of higher-frequency light. These mercury-vapor "sun lamps" are available for health purposes and for many commercial uses. Used with special glass filters which absorb the visible rays, they are powerful sources of invisible light with which to study fluorescent materials.

MINING

In prospecting for minerals it is necessary to use very high-frequency ultraviolet light from a mercury arc enclosed in a quartz tube. Ordinary glass is not transparent to high-frequency light. An electric arc in low-pressure mercury vapor is rich with invisible high-frequency rays, but it is bright with visible light. Hence there must be a special filter to remove as much as possible of the visible light. The chief difficulty lies in securing a filter glass which will remove the visible light without also stopping the high-frequency ultraviolet rays. The best glass filter available is Corning 986, which transmits from visible violet up to about 2,537 angstroms, or the center of "middle ultraviolet." This will fluoresce willemite and scheelite and also pass erythematous health rays and some germicidal rays.

Most commercial lamps have imperfect filters which pass too much visible and not enough of the very-high-frequency light. This may result in poor tests due to color confusion. High-pressure lamps give more high frequency if the outer glass globes are removed.

Different materials which fluoresce the same color may require widely different excitation frequencies. Recognizing this important fact, the author has invented a test lamp which radiates two or more beams of different frequencies. This lamp makes the determination of ores, such as scheelite, more precise and makes it possible to avoid expensive errors. If such a lamp cannot be secured, and one is using a high-frequency lamp which fluoresces scheelite, check further with some low-frequency lamp such as the Purple-X incandescent lamp.

The test lamp should be used in total darkness, at night or in a dark room. Time should be allowed for the human eye to become sensitive to the dim light of fluorescence. When visible light is used it also should be dim and shielded to avoid glare. Avoid looking directly into the ultraviolet light, as it may be harmful to the eyes.

Whenever possible it is best to bring specimens to a high-power lamp operating from a 120-volt a-c transformer. When this is not feasible, a smaller portable lamp, with battery-operated vibrator, may be taken to specimens in the field. Prospecting with fluorescence is new and often misinterpreted. However, good lamps, are not too expensive, they give immediate results and have become very popular aids in prospecting, mining, and milling.

Table II. Utah Minerals Which Fluoresce

Name	Location	Colors* by Fluorescence	Colors* by Phosphorescence
Agate	Jericho, Joy, Topaz, gen.*	Y., G.	
Alabaster	S.E. and gen.	Y. W.	W.
Alunite	Marysville	Pale W.	
Aragonite	Abundant, gen.	Y., W., R.	W.
Autunite	Eastern Utah, Paria	Y., G.	
Barite	Green River, Tooele	Y., W.	W.
Calcite	Pelican Pt., gen.	P., R., Bl.	R., W.
Calamine	Tintic, gen.	Y., G.	
Cerussite	Park City, gen.	Pale Bl.	
Chalcedony	Joy, Topaz Mt., gen.	G., Y.	
Cinnabar	Mercur, Wash. Co.	Mercury shadows	
Coal	Carbon Co., gen.	Every color	Every
Jasper	San Rafael, Green River, Joy	G., Y.	
Cuprotungstate	Gold Hill	Y.	W.
Dolomite	Gen.	Bl. W.	
Elaterite	Uinta Basin	Br.	
Flint	Gen.	Y., G.	
Fluorite	Drum Mts.	Bl.	W.
Gypsum	Eureka, gen.	G.	
Halite	Redmond	Slightly R.	
Hydrozincite	Hidden Treasure	Bl., Y., Pur.	
	Horn Silver Mine, gen.	Bl.	W.
Limestone	Gen.	W., Y., Bl.	Y., W.
Lime incrustations	Grouse Creek, gen.	Y., W., Bl.	Same
Marble limestone	Gen.	Various colors	W., Y.
Opal	Gold Hill, Topaz, Alta	G., Y., W.	
Opalized wood	Gen.	Various, G.	
Petrified wood	Heber, Wayne Co., gen.	Y., R., G.	
Petroleum	Wash. Co.	Bl.	
Powellite	Milford Dist., Alta, gen.	Y., O.	Y.
Quartz geode	Green River	Bl., W.	W.
Incrusted crystals	Park City Mines	R.	
Scheelite	Alta, Box Elder, gen. Lucin, Gold Hill, Milford, W. Tintic	Bl. W.	
Scheelite and molybdenum	W. Tintic, Gold Hill	Golden cream	Y., W.
Siderite	Newhouse	Pale Bl.	
Sphalerite	Beaver, Park City	Bl., bright gold	
Smithsonite	Hidden Treasure	G.	G.
Stalactites	Caves	Light Y.	Same
Travertine	Mosida, Topliff, gen.	Y., Br.	Y.
Tungstite	Gold Hill		
Willemite	Milford, Talisman	G.	W.
Willemite and mimetite	Beaver Co.	Pale Y., R.	Same
Wollastonite	Gen.	Y.	
Zoisite	Mineral Range	Pur., Y.	
Zoisite with scheelite		Bl. spots	
Zippeite	So. Utah	Brilliant Y., G.	

* Abbreviations used in table are: Gen., general; Y., yellow; G., green; W., white; R., red; P., pink; Bl., blue; Br., brown; Pur., purple; and O., orange.

ROCKS WHICH FLUORESCE

We have tested many Utah minerals. Those which fluoresced are listed in Table II, with the colors of the reradiated light and the places where found. Of course the list is not complete and will be amplified by further tests.

Similar rocks from other states, for the most part, fluoresce in the same general way. The fluorescent colors

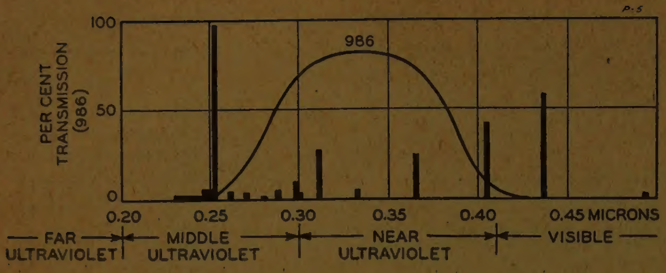

Figure 5. Relative intensities of mercury lines before transmission through tubes and by Corning 986 filter glass

vary with the chemicals contained in each specimen and, therefore, with the locality, and somewhat with the type of lamp used. Too much or too little of an impurity may totally prevent fluorescence. Colors emitted from a specimen by fluorescence and phosphorescence often are entirely different.

THE FUTURE

Chemical analysis which depends on the human eye for measuring fluorescence is only approximate, and yet it has accomplished marvels. Whenever laboratories begin to analyze the fluorescent colors by spectroscopy and to measure their intensity with a photoelectric device, the results will be a thousand times more accurate. Then, qualitative and quantitative analysis by fluorescence will be far more valuable than now. Then, every change in wave length, brilliance, and purity of fluorescent color will interpret the atomic mysteries within complicated materials.

Electronic Graphical Symbols Standardized

Prior to 1918 only a few vacuum tubes of a simple type, usually a glass envelope enclosing a filament, a plate, and a control grid, were in use. Recently, especially in the war program, they constantly are being applied in new fields and the demands of the Armed Forces, particularly for communication and electrical detecting devices, have accelerated their use to an unprecedented degree. Even in civilian life the expansion will be noticeable: four or more types of tubes now will be used in every home radio receiver and in manufacturing processes many types of control equipment incorporate electronic devices.

As a result electronic devices have become so complicated in structure that simple picturization on drawings is no longer feasible. For this reason an approved American Standard Z32.10-1944 co-ordinating and standardizing graphical symbols depicting electronic devices on drawings has just been completed by a committee working under the sponsorship of the AIEE and The American Society of Mechanical Engineers. In the new Standard the graphical symbols for electronic devices have been made a study in themselves, for, although they always are used as a part of power or communication circuit drawings, the devices really belong to a distinct class.

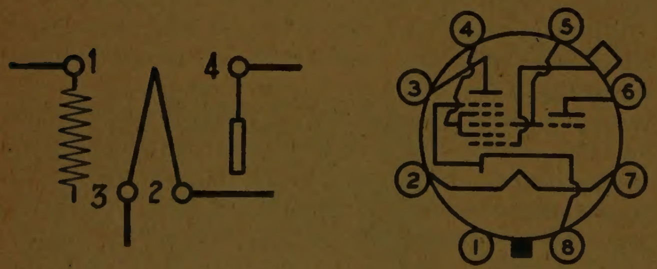

Figure 1. At the left is a typical picturization of a 1916 model of an amplifier tube. Represented by the resistor symbol, the grid was supposed to depict the resistance of the flow of electrons from the cathode to the plate, the former being the simple filament type and the latter a simple surface. The tube envelope is not even represented. On the right, a triode-heptode with rigid envelope connections and basing information becomes quite a complex diagram of connections when all this information is shown

In the Standard, the symbols for the tube components are followed by typical applications showing their use in various classes of devices such as the thermionic, cold-cathode, and photoemissive devices of varying structures and combinations of elements as triodes, pentodes, cathode-ray tubes, magnetrons, and velocity-modulation tubes. To formulate a symbol for any specific tube, the components are selected from the list given or are made by the assembling of component symbols.

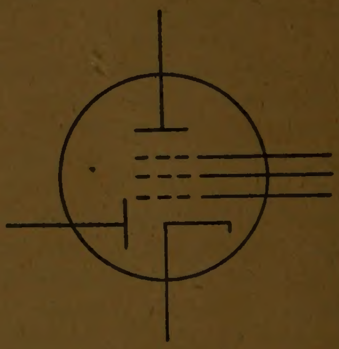

Figure 2. This simplified diagram of a diode-pentode with pentode amplification added to the tube is representative of those recommended by the new Standard

The symbols for electronic devices are intended primarily to indicate only electrical functions, although their respective physical pattern may be indicated in some cases where basing diagrams are required. In general the physical relation of component parts of a piece of apparatus appears as far as possible without undue complication of the symbol or drawing.

Symbol sizes and line widths as depicted in the Standard have been designed for average drawing use and, when reduced two to one, result in sizes which seem most desirable for publication. The size and width of lines may be altered as required, although it is believed that the sizes shown in the Standard are the best possible for general usage. Wires need not be brought into the symbol in any particular position but may be varied as required to simplify the wiring pattern in a specific circuit drawing.

Fluorescent Lighting of Aircraft Instruments

A. D. DIRCKSEN
ASSOCIATE AIEE

Lighting of instruments in airplanes by the use of indicator markings that fluoresce when bathed in ultraviolet radiation is one of the latest developments that adds to the convenience and safety of the crew. The light is not detectable by enemy airmen, does not cause unwanted reflections, and does not impair night vision. Through several stages of development, a blue fluorescent mercury-vapor lamp which operates on the 24-volt d-c system of the airplane has been produced for generating the ultraviolet radiation.

INSTRUMENT ILLUMINATION by ultraviolet flood lighting is the use of near ultraviolet rays to activate the fluorescent and luminous markings on aircraft instruments to produce a uniformly illuminated instrument panel with no apparent visible light in the cockpit. Ultraviolet radiation also is called "black light" commercially.

The radiation used in this application is in the near ultraviolet region which is just below the visible portion of the light spectrum. It may be obtained from blue fluorescent, argon glow, and mercury-vapor lamps, and also from incandescent lamps operated at a high filament temperature which produces high light output at the expense of short lamp life. Of these lamps, the most efficient source for this radiation is the blue fluorescent lamp with a special blue phosphor powder.

The fluorescent instrument lighting system, including the blue fluorescent lamps, the lamp assemblies, and related operating equipment (including the vibrator inverter), has been developed by the Engineering Division, Wright Field, in conjunction with the lamp and fixture manufacturers.

Fluorescent ultraviolet instrument lighting replaced the unsatisfactory type of individual instrument lighting by direction of the Chief of the Air Corps (now Army Air Forces) in January 1940. Steps were being taken at that time for service test of the fluorescent ultraviolet lighting system. Accelerated comparative flight tests were conducted at Wright Field on the individual instrument lighting and lighting by ultraviolet radiation from argon and blue fluorescent lamps. The fluorescent system was by far the best as the near ultraviolet radiation obtained from the blue fluorescent lamps was in excess of that required for the worst conditions of dawn and dusk. Because of this property of the lamp, a dense ultraviolet filter was used to eliminate nearly all traces of visible light in order to permit operation in a cockpit of practically total darkness so as to improve the dark adaptation of the crew for night operation and to minimize reflections in the windshield and canopy. The argon lamp, with thin ultraviolet filter, provides insufficient radiation to produce clear and well defined numerals, and unless placed very close to the instruments adds little to the original brightness of the self-luminous material. The self-luminous material (greenish color) has been changed to orange fluorescent material in order to improve the dark adaptation of the crew for night operations. However, a few

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Essential substance of an address presented before the AIEE Dayton Section, February 2, 1944, in Dayton, Ohio.

navigational instruments retain limited markings of self-luminous material (orange) for safety in case of failure of the lighting or electrical systems.

The blue fluorescent lamp is a mercury-vapor lamp which has a coating of fluorescent material on the inside of the bulb. This coating transforms the short ultraviolet rays of 2,537 angstroms to near ultraviolet rays of a wave length of 3,650 angstroms. The radiation emitted from the blue fluorescent lamp assemblies, with the ultraviolet-light transmitting filter glass, is of the near ultraviolet light, as shown by curve *A* of Figure 1, and is not injurious to the eyes or skin. The harmful ultraviolet rays are absorbed by the glass bulb of the lamp and the filter. The emission of the blue fluorescent lamp alone is shown by curve *F* which peaks at 4,400 angstroms and the filter peaks at approximately 3,650 angstroms, at which value the fluorescent material used for the dial and pointer markings functions most efficiently.

The near-ultraviolet rays emitted from the lamp assemblies are harmless; however, the assemblies should be mounted between the operator and the panel and directed so that none of the direct rays reach the eyes of the operator. These rays may cause fluorescence of the eyeballs resulting in discomfort and temporary impairment of vision which destroys dark adaptation and appears as a light fog; however, no ill affects will result. With the lamp assemblies properly mounted and directed toward the instrument board there is no discomfort or annoyance to the operator but a pleasing uniformly illuminated instrument panel. The reflection of near-ultraviolet radiation from the dark-colored instrument panel and cockpit is practically negligible. Extensive flight tests indicate no eye strain or discomfort when compared to other types of instrument lighting.

DEVELOPMENT OF THE FIRST SUCCESSFUL LAMPS

Because of the necessity for locating the lamp assembly between operator and instrument panel, it was not possible to use the standard 15-watt 18-inch 110-volt blue fluorescent lamp, and the lamp industry therefore was requested by the Matériel Command to develop a small 110-volt blue fluorescent tubular lamp. The result was designs for a four-watt lamp six inches long, and a six-watt lamp nine inches long. Only the four-watt lamp was standardized in order to minimize the number of types of lamps and lamp assemblies.

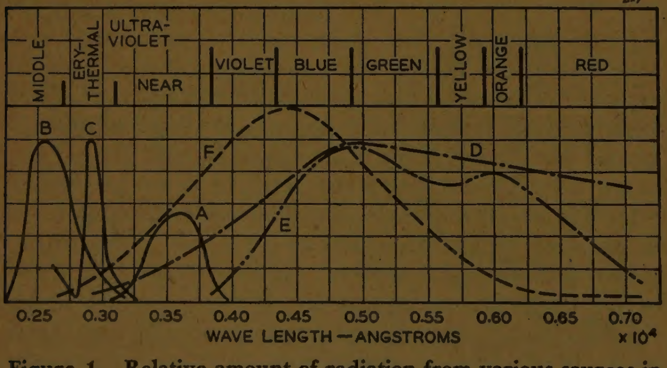

Figure 1. Relative amount of radiation from various sources in the ultraviolet and visible portions of the spectrum

A—Near-ultraviolet light passed by filter glass used with fluorescent lamp assembly
B—Germicidal lamp
C—Sun lamp
D—Daylight
E—Daylight fluorescent lamp
F—Blue fluorescent lamp

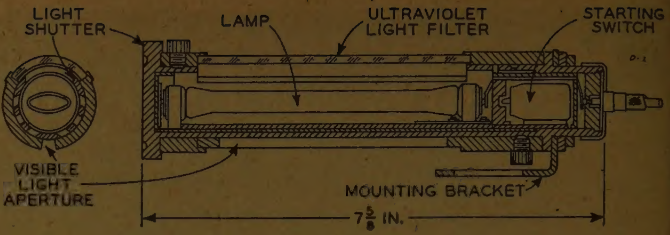

Figure 2. Fixed type of cockpit fluorescent lamp assembly for 110-volt a-c operation

After these lamps were developed it was necessary to obtain a suitable lamp ballast, which is a series choke coil to limit the lamp current to 145 milliamperes at 115 volts alternating current. It was also necessary to obtain a suitable neon-glow automatic-starting switch, and inverters to change 12- and 24-volt direct current to 110-volt alternating current for operation of the four-watt 110-volt tubular lamp. To reduce the inverter to minimum size and weight, the vibrator type was selected and designed for operation at a frequency of approximately 180 cycles per second, with the series choke coil incorporated in the transformer. A three-volt a-c output was also provided from a separate secondary winding on the transformer to provide a limited amount of three-volt power for the compass light, bomb indicator lamps, and miscellaneous three-volt lamps. If the airplane is already supplied with a 110-volt 400-cycle rotary inverter, the vibrator type of inverter is not required and is replaced by an auxiliary box, containing two or four (as required) 400-cycle choke coils to be connected in series with the power supply and the lamp assemblies. The system operates in a manner similar to the usual commercial 15- or 20-watt fluorescent lamps with self-starting switches of the neon-glow type.

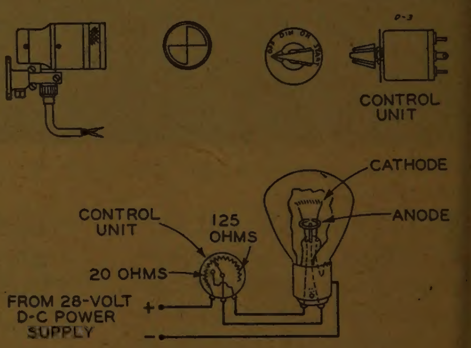

Figure 3. Cockpit fluorescent lamp assembly for 24-volt d-c operation

The first fluorescent ultraviolet lamp assemblies standardized by the Army Air Forces were a fixed and a flexible type. The lamp housings of each lamp assembly are identical except a 12-inch flexible arm is supplied in the flexible type instead of a fixed bracket. The flexible lamp assembly is intended for use on fighter or single-cockpit-type airplanes that normally use a stick-type control, and when in use is placed approximately over the control stick to produce a uniformly floodlighted instrument panel. When not in use it is fastened, clipped, or pushed to the side of the cockpit. The fixed-type assembly is normally located on the control column, the underside surface of the light shield, the side of the fuselage, or the control pedestal. The lights should not be located overhead, but the light beams should be retained as much as possible under the instrument panel light shield and between the operator and the instrument panel. The lamp assemblies are designed also to produce selective visible

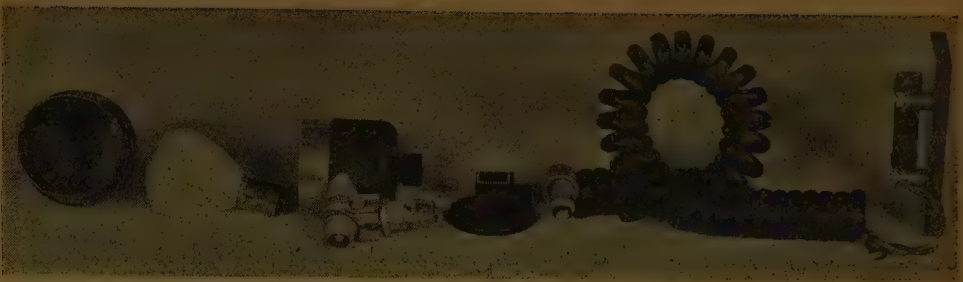

Figure 4. A 24-volt d-c fluorescent ultraviolet lamp with starting and on–off switches incorporated in the lamp assembly

light by rotating the lamp filter housing 180 degrees for illuminating maps and for floodlighting the cockpit, if desired, with visible (blue) light when flying by instruments in bad weather, and have included in the base the automatic-starting switch of the neon-glow type, which is designed so as to serve also as a connector receptacle. Figure 2 shows such a lamp assembly.

REDUCTION IN SIZE OF LAMP ASSEMBLIES

In some installations, difficulty was encountered in satisfactorily locating the lamp assemblies because of their size, so smaller assemblies were then developed in which the length was reduced and the diameter was reduced to approximately one half that of the first type as described in preceding paragraphs. These units were fabricated with a lamp housing and a lamp cartridge but did not include the visible light feature.

The lamp cartridge consists of a special fluorescent lamp comprising a tubular ultraviolet-light filter bulb, and a small neon-type glow switch connected to the lamp terminals, mounted in a metal housing which includes a series of holes and an aperture for the light shutter. To change the output, the knob on the end of the housing shell, which fits into a boss on the lamp cartridge, is turned to rotate the lamp cartridge to place the proper aperture in line with the aperture of the lamp assembly housing. The control switch is in the input circuit of the vibrator-type inverter.

LAMPS FOR LOW-VOLTAGE D-C OPERATION

The lamp industry was requested to develop a 24-volt d-c blue fluorescent lamp for operation directly from the standard 24-volt d-c electric system, thus eliminating the need for the vibrator inverter. The result was the present four-watt blue fluorescent lamp with indexing (polarized) bayonet candelabra base shown in Figure 3. At this time a new and more efficient phosphor was developed and used to obtain approximately the same light output as the four-watt, 110-volt lamp. It also became possible to simplify the four-watt 110-volt tubular lamp by using this new phosphor with a round instead of a flat bulb.

A small light-weight fixture was designed to house the new four-watt 24-volt lamp for use as a cockpit light. This unit is operated by a rheostat-type control unit that includes the series ballast (20 ohms) for the lamp, a dimming rheostat of 125 ohms, on-off switch, and manual starting switch. Dimming is accomplished by reducing the voltage on the lamp. The lamp assembly housing has a slotted filter arrangement to obtain selective visible and ultraviolet light by rotating the lens housing head. The control unit is so designed that the contact arm is held in the start position for a few seconds to heat the lamp filament and vaporize the mercury. The arc is made upon release of this starting switch by the spring pressure to the "on" position of the control unit.

The 24-volt four-watt blue fluorescent lamps provide uniform floodlighting that is not detectable by enemy aircraft with the least weight and power consumption of any lighting system heretofore used by the Army Air Forces.

STATUS OF CURRENT DEVELOPMENTS

A recent development, shown in Figure 4, proposes the use of an iris-type light shutter to reduce the light output from 100 per cent to zero instead of dimming by rheostatic control, which could not be complete lest the arc go out at approximately five per cent of maximum ultraviolet-light output. This type is designed to give selective visible and ultraviolet light by rotating the filter housing cap. A retractable cord has been developed for this light which will result in a minimum amount of free length of cord to foul the controls and permit hand operation of the light for reading maps and searching in the cockpit.

Tests are also being conducted on a self-starting lamp circuit using the standard four-watt 24-volt blue fluorescent lamp.

It is difficult to locate ultraviolet lamps in the bombardier's compartment that will illuminate the fluorescent markings of the bombsight, the fluorescent bombing tables and charts, and the instruments. Therefore, a suitable headband, which permits the bombardier to have free use of two hands, has been developed, for which a normal stowage position is located near the instrument panel to illuminate the instruments until the bombardier is required to operate the charts, bombing tables, and bombsight.

Accuracy of Control Devices for Feeder-Voltage Regulators

A standard for the specification of accuracy tolerance and for the establishment of accuracy classifications for voltage regulators is under preparation by the AIEE transformer subcommittee. This article, discussing the application and characteristics of such regulators, has been prepared in order that engineers interested in system design may be informed of the nature and effect of errors in the regulator control system.

THE transformer subcommittee of the AIEE electrical machinery committee has undertaken a study of the factors involved in the performance characteristics of feeder-voltage regulators in order to lay the ground work for preparing standards which this type of apparatus must meet to insure adequate performance. Because voltage regulators are important elements in most transmission and distribution systems, the transformer subcommittee felt that a discussion of their characteristics would benefit the industry.

GENERAL

The control equipment for feeder-voltage regulators consists essentially of a voltage-responsive relay called a "voltage-regulating relay" and a source of potential to indicate the voltage at the regulator output terminals. These serve to control the operation of the regulator so that the output voltage can be held at a desired value under certain predetermined conditions.

As an auxiliary to the voltage-regulating relay, there may be a "line-drop compensator" which simulates the voltage drop in the actual (or hypothetical) circuit being regulated. This voltage is approximately proportional to the line drop and is introduced in series with the regulator voltage applied to the control element. The regulator is thereby enabled to maintain desired voltages at points remote from the point of installation.

Other auxiliary devices may include time-delay relays, limit switches, control and protective relays of various kinds, and other equipment required to perform specific functions.

As the control voltage drops somewhat below the value for which the voltage-regulating relay is set, contacts are closed which energize some means for increasing the output voltage. Likewise, as the control voltage exceeds the value for which the relay is set, other contacts are closed which energize means for reducing the output voltage. The difference between the values of the control voltage, which caused the "raise" and "lower" contacts to operate, is known as the "relay band width." The magnitude of this band width affects the frequency with which the regulator functions, since the smaller the band width, the more operations will occur in holding output voltage within desired limits. If the band width is too small the regulator will be in almost continuous operation. In the case of step-voltage regulators, the voltage-regulating-relay band width must, of course, be somewhat larger than the voltage steps to prevent hunting or pumping. The relay band width of all regulators is adjustable.

The effectiveness of the entire regulator is directly dependent upon the operation of the control devices and any inherent lack of accuracy in their component parts is of serious concern. Erratic performance of voltage regulators due to inaccuracies of their control devices may require excessive system investments to avoid unsatisfactory customer voltages and consequent customer complaints. One might also question whether errors in the control devices affect the availability of the full range of the regulator or limit the range of bus voltage over which satisfactory regulation is attainable. Before these questions can be discussed adequately, consideration must be given in some detail to the functional requirements of the regulator and its control device and the effects of inadequacies upon the system voltages.

SYSTEM CHARACTERISTICS

Even with a perfect regulator, the voltage along a distribution circuit would vary with location, loading, and time. It is recognized that some tolerance in voltage magnitude at the customer's service entrance must be allowed. The characteristics of utilization devices determine the allowable upper and lower limits of the design voltage spread.

Figure 1a is a schematic diagram of a typical distribution circuit. Figure 1b shows the voltage distribution throughout the circuit for light-load and full-load conditions. All voltages are given in terms of an equivalent 120-volt base. The full-load voltage allocations which are representative of accepted practice are eight volts drop in the feeders, three volts drop in the primary mains and laterals (feed point to primary of last transformer), four volts drop in the distribution transformers, three volts drop in the secondary, and one volt in the service. At extreme light loads, these voltage drops are assumed to be 25 per cent of their maximum value.

It should be noted that the desired full-load voltage at the first transformer is 125 volts, while the desired light-load voltage at this point is much lower, or slightly over 121 volts. The reason for this is that during the short period of primary-circuit full load, it is very desirable that the voltage on the primary side of the first transformer be held at a high value to compensate for the probable large drop in transformer, secondary, and service, while during the many hours of the day and the season of the year when the primary-circuit load is appreciably less than the maximum value, it is equally desirable that the voltage at the first transformer be held at a lower value to prevent undue shortening of the life of lamps and many other devices which are normally in use for long periods during the day. Peak loads on a distribution circuit are of very

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This report, sponsored by the transformer subcommittee of the AIEE committee on electrical machinery (M. S. Oldacre, chairman), was prepared by a working group consisting of J. E. Clem, J. R. North, W. C. Sealey, and C. F. Wagner, chairman.

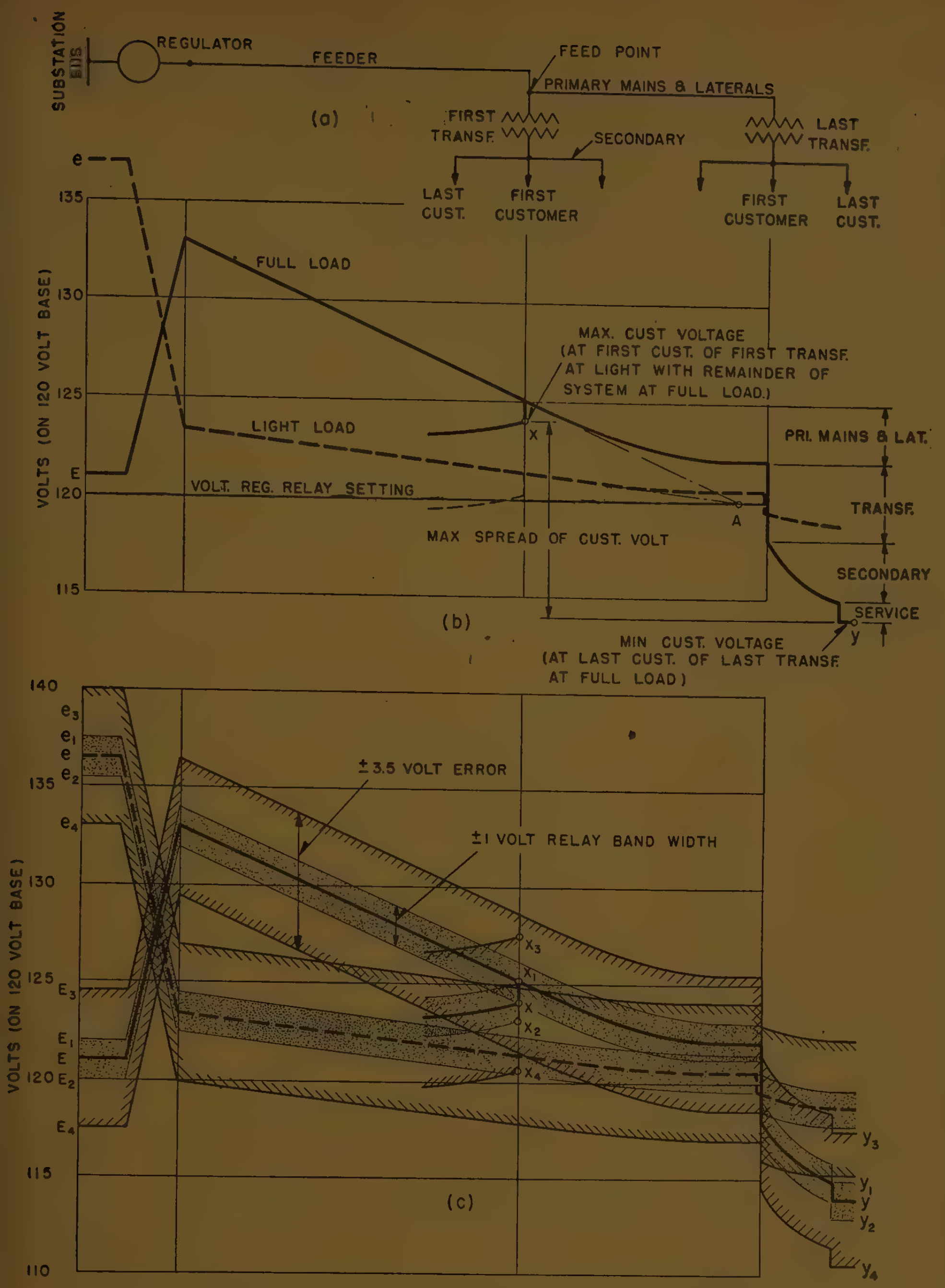

Figure 1. Effect of control-device error upon voltage along distribution circuit

short duration and exist only a few hours during the year. It is equally important not to let the utilization voltage become too low during the short peak period or too high during the very long off-peak period.

The regulator setting to achieve the given light- and full-load distribution curves is determined by the intersection, *A*, of the projections of the two voltage curves for the feeder. Thus the voltage-regulating relay must be set to 120 volts and, since the compensator responds only to the current in the feeder, its impedance must be adjusted to a fictitious length equal to that from the regulator to the intersection *A*. With the regulator at full "buck" the substation bus voltage at light loads can be as high as 137 volts and at full "boost" at full load as low as 121 volts. It should be noted that the design requirements, as based on paragraph 6.002 of the 1942 American Standards Association Transformer Standard *C*-57, are 132 volts or 110 per cent of rated voltage of the regulator at no load, and 126 volts or 105 per cent of rated regulator voltage at full load.

With the foregoing assumptions, the minimum voltage at a customer's service entrance occurs under full load at the last customer in the secondary of the last transformer (speaking electrically) on the last lateral. This point is indicated by y and equals 114 volts. The maximum voltage occurs at the first customer on the secondary of the first transformer when this particular transformer is lightly loaded but the system as a whole is at full load. This point is indicated by x and equals 124 volts for this system. The total service voltage spread is ten volts. At any one customer the spread is not this great. The occurrence of light loads on the first transformer with full loads on the remainder of the distribution circuit involves some element of probability, but nevertheless it is generally agreed it must be provided for. The voltages at light load fall within the values discussed and therefore do not constitute a limitation.

Figure 1c depicts the effect of the voltage-regulating-relay band width and errors in the control device upon the performance of the system. The shaded portion applies to a voltage-regulating relay set in the same manner as for Figure 1a except that the relay band width is ±1 volt (0.8 per cent). Because of lack of control within this band the voltage at any location can fall anywhere within the band so marked. At full load the minimum service voltage—occurring again at the last customer connected to the last transformer—is y_1 instead of y, a value one volt less. If in attempting to regulate for this voltage the substation bus is 121 volts (as assumed in the first case) the regulator does not have to take its full "boost" position. Using the full capability of the regulator the substation bus can drop to E_2 (120 volts) without dropping the minimum service voltage below y_2.

To determine the maximum voltage that might be obtained at a customer's service entrance, consideration must be given to the upper border of the band of regulation, which gives rise to the value x_1 (125 volts). Here, however, more definite consideration must be given to the manner in which the substation-bus voltage varies. If it is assumed that at full load on the feeder the substation-bus voltage always lies between E and E_2 then even if the regulator is attempting to regulate for a value of x_1 at the

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first customer of the first transformer, this value of x_1 is unattainable because even with full "boost" the value of x cannot be exceeded. On the other hand, if the assumption is made that for full load on the feeder the substation bus voltage might have any value near E but not below it, then the bus voltage might have the value E_1 while the regulator is attempting to regulate on the upper border of range and therefore the maximum voltage on a customer's service is x_1. A similar condition applies for larger values of substation voltage for full load in the feeder except that the regulator need not use full "boost" positions. The light-load voltages fall within the limits mentioned. Therefore, it may be concluded that for the conditions assumed a ± one-volt relay band width decreases the minimum voltage at customer's service entrance by one volt and increases the maximum voltage between zero and one volt depending upon the assumptions made with regard to the substation-bus voltage.

Distribution system design must allow for a reasonable voltage-regulating-relay band width and the shaded portion of Figure 1c shows a representative condition with a service voltage spread of 12 volts (125 volts at x_1 to 113 volts at y_2). This 12-volt service-voltage spread corresponds to the preferred utilization-voltage spread (with three volts drop in interior wiring) of Edison Electric Institute publication No. *J8*, "Utilization Voltage Standardization Recommendations," and with the voltage profile shown as Figure 6 in the EEI report.

Figure 1c also shows the voltage distribution along a distribution circuit when, in addition to the ± one-volt relay band width the voltage-control relay has an additional error of ±2.5 volts, making a total error of ±3.5 volts or say, ± three per cent. Under this condition, the minimum voltage at the customer's service y_4, is reduced by 3.5 volts to 110.5 volts, and the maximum customer voltage, which occurs again at the first customer of the first transformer while the remainder of the system is fully loaded, is x_3, and equals 127.5 volts. Again this maximum voltage is based upon the assumption that the substation voltage might have any voltage in the neighborhood of E but not below it. If the full-load voltage of the substation bus equals E, the maximum customer's service voltage is x. Thus, the minimum voltage is 110.5 and the maximum voltage lies between 125 and 127.5 volts.

With the control relay and compensator adjusted for the settings indicated in Figure 1b, the full-load condition sets both the maximum and minimum voltages at the service entrances. The light-load values fall within these limits. There exists, therefore, some tolerance for which light-load values can be set. In Figure 2b an alternate adjustment is indicated for which the voltage at the feed point is fixed at 125 volts at both light and full load. This adjustment is accomplished by setting the relay for 125 volts and the compensator for a drop corresponding to that of the feeder impedance to the feed point. With this setting the maximum voltage at the service entrance at light loads equals x. The advantage of this setting over that of Figure 1b is that it permits a greater variation in the substation-bus voltage at the expense, however, of greater variation of the voltage of individual customers. With the setting of Figure 2b the variation of voltage between light load and full load would be more noticeable to certain customers. The effect of errors in the control devices would be substantially the same.

Generalizing upon the effect of control errors, it may be seen that a ±n-volt error may reduce the minimum voltage at customer's service entrance by n volts and increase the maximum customer voltage between zero and n volts depending upon the manner in which the substation bus voltage varies. The total variation of customer voltage may thus be increased between zero and $2n$ volts. If, however, the recommended service-voltage spread indicated by the shaded area of Figure 1c is not to be exceeded, the voltage at the first customer must not be greater than 125 volts and the voltage at the last customer's entrance must not be less than 113 volts. To maintain these voltages, the design voltage spread of ten volts, as indicated in Figure 1b, must be reduced by five volts (±2.5 volts), or in other words, the impedance of the distribution circuit beyond the "feed point" must be halved to provide adequate voltage to all customers. This may require doubling the distribution facilities beyond this point. The error increases the maximum range over which the bus voltage may vary and in this regard does not limit the availability of the full kilovolt-ampere capacity of the regulator.

IMPORTANCE OF ERRORS

The error of ±3.5 volts used in preparing Figure 1 constitutes an assumed cumulative error of ±3.5 volts and represents some present-day regulators on the basis that all the errors may occur simultaneously and be in the same direction. The errors vary slowly with temperature, load, and frequency. Their coincidence and frequency of occurrence is a function of the law of probability.

It is evident that with an assumed cumulative error of ±2.5 volts in the control equipment, and with a relay band width of ± one volt, which is a minimum practical value, some seven volts or about six per cent of the total regulating range is unusable. The regulator may therefore be only about 70 per cent effective. This assumes that all the errors are cumulative, occur at the same time, are of the same magnitude at light load as at full load, and that the errors operate to limit the buck as well as boost operation of the regulator. If the guaranteed performance of the regulating equipment is based on the cumulative occurrences of these errors, the user has no

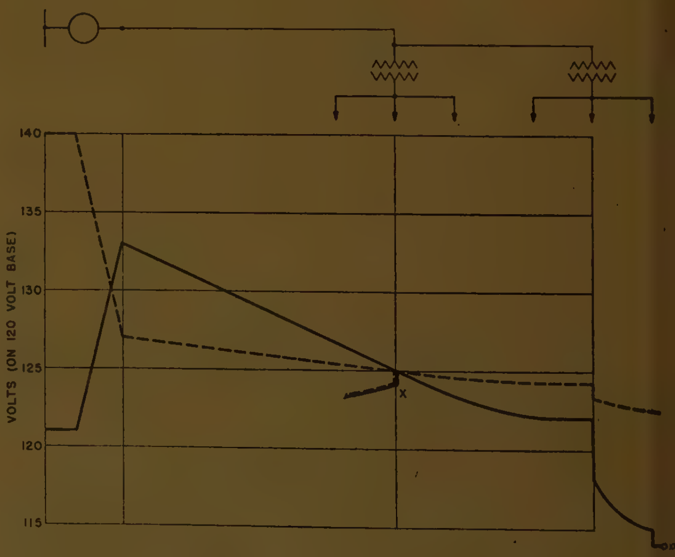

Figure 2. Voltage along distribution circuit with voltage at feed point equal to 125 volts at both light-load and full-load condition

choice but to base distribution-circuit design upon this guarantee.

To maintain the same limits of customer voltage with an error in the control device as without error requires liberalizing of the distribution system either through over-installation of transformers or through reduction of the impedance of the primary mains and laterals. Some idea of the probable cost of additional system strengthening which may be required can be obtained from an analysis of the investment in transformer-secondary combinations on residential circuits designed for different voltage-drop limits. The increased cost of these transformer-secondary combinations designed for one volt less drop is in the order of two dollars or more per kilovolt-ampere of diversified circuit demand for 4,160-volt circuits, and in the order of three dollars or more per kilovolt-ampere for 7,200-volt circuits. The value of adequate regulation may be even better appreciated if it is realized that ordinarily there are about ten volts to "spend" in the design of distribution circuits and each volt lost due to inadequate regulator performance represents one volt out of ten (rather than one volt out of 120 volts) in the measurement of increased investment required. It may be possible to design and build regulators having better performance characteristics without too great an increase in cost. If so, an over-all improvement in the economics of distribution may reasonably be effected by investing more money in regulators of improved performance characteristics, thereby affording a greater saving in the distribution circuit itself.

The accuracy requirement for voltage-regulator control depends upon the length of the circuit as well as upon the range of satisfactory voltage to the user. If the regulator is located at or close to the load less accurate control is required for the same range of utilization voltage than if the loads are distributed over the length of a long line having considerable voltage drop.

ACCURACY OF REGULATOR PERFORMANCE

The various factors involved when considering the over-all accuracy of feeder-voltage regulators should be divided into two general classifications. These are: first, errors incident to the design and manufacture for which limiting values may be established and compliance therewith verified by a factory test; second, other factors which may be affected by the application or by adjustment, or which may not be subject to verification by a factory test.

FACTORS INCIDENT TO THE DESIGN AND MANUFACTURE

These include the following:

1. *Ratio errors in the potential transformer or potential supply winding.* These should include (*a*) the ratio error with no load in the regulator, and (*b*) the effect of the load current and regulator position on the ratio error. The only burden on the potential transformer or potential supply is the voltage-regulating relay. Regardless of the magnitude of the load on the regulator this burden introduces an error that is essentially constant and can be compensated by the balance adjustment of the voltage-regulating relay. An indicating instrument connected across the voltage-regulating relay may not be a true measure of the voltage across the primary of the regulator.

2. *Errors in the voltage-regulating relay and the associated control circuits.* It is understood that some present designs have been influenced by a desire to keep the control equipment losses to an absolute minimum. Perhaps this consideration has been unduly emphasized.

3. *Ratio errors in current transformers used to energize line-drop compensators.* Limiting values of these errors should be based upon loading the current transformer with an impedance that ranges from zero to such a value that will introduce into the supply for the regulating relay a voltage equal, at rated regulator current and expressed as a percentage of that supplied by the potential winding at rated voltage, to the maximum boost percentage of the regulator. The current through the secondary of the current transformer should vary from a value corresponding to 0 to 100 per cent of the rated value of the series winding of the regulator. It is customary, however, to supply a 24-volt (20 per cent) compensator. The value of 24 volts was fixed upon so that the same control system could be used on either a ±10-per-cent or ± 20-per-cent regulator. Actually in the extreme application the compensator should be good for the entire range (20 per cent on a ± 10-per-cent regulator) but the more usual operating point is closer to the maximum-raise range. The use of a 24-volt compensator provides for the extreme case for a ± 10-per-cent regulator and the more usual case for a ± 20-per-cent regulator.

It has been suggested that the limiting regulator error based upon the foregoing factors should not be exceeded over a frequency range of ±0.5 per cent (±0.3 cycle on a 60-cycle system) and over a range of external ambient temperature from −30 to +40 degrees centigrade. The voltage-regulating relay and other equipment will usually be mounted inside some type of container or housing and will, therefore, operate at a temperature in excess of the maximum ambient temperature of 40 degrees centigrade. Since the temperature inside the container, or housing, will vary with the temperature design of the housing, it is better to specify that the relay must meet its performance specification in an ambient temperature of 40 degrees centigrade outside the regulator housing than on the basis of specifying a fixed maximum temperature within the enclosure.

In considering the effects of temperature, the variations of the temperature of the conductor, whose impedance determines the regulator setting should likewise be borne in mind. Between light load on a very cold day and full load on a very hot day the resistance of the line might change as much as ±20 per cent from a mean value. This may result in a variance of regulated voltages of as much as ±1.0 per cent when using a compensator whose resistor is constant over the entire temperature range. So-called temperature errors in the compensator usually reduce the magnitude of this variance. The amount of compensator error is affected by whether the regulator is located indoors or outdoors. Since present thought is centered about errors of about 1.0 per cent, the variance due to conductor temperature may equal or exceed the total error of the control system.

OTHER FACTORS

These include the following:

1. *Line-drop compensator taps.* It has been difficult to design a tapped reactor, such as may be used for the reactance element of the compensator, to obtain a definite amount of reactance on all taps without some error. Errors of this style are constant and can be compensated to some extent by the operator when the compensator is adjusted. Since the load distribution on a distribution circuit is continually changing, checking the performance of the reactance element of the line-drop compensator with field voltmeter readings at any single location is extremely cumbersome and difficult. The regulator performance is best measured by determining the voltage conditions at the point of first and last customer

for the maximum and minimum load conditions. Graphic voltmeter charts are not always sufficiently accurate to check regulator control settings.

2. *Relay band width.* It is recognized that there is a minimum practical band width which can be obtained within economic limitation of design. However, the operator may adjust the relay to obtain any value of band width from the designed minimum value up to the designed maximum value.

3. *Change in calibration of the voltage-regulating relay over a specified period of time or the so-called "drift."* Change in calibration may be caused by mechanical wear due to dust, moisture, friction, and an undue amount of rough handling of the movable parts of the relay. This is a factor which cannot be checked or demonstrated by any reasonable factory test. Limiting specifications should not be incurred where it is impossible to demonstrate that a device can or cannot meet the specifications. Furthermore, since the "drift" of a voltage-regulating relay is affected by the wear and tear on the device in actual use, any specification covering this item is fundamentally a specification covering the life of the device. Regardless of the guarantee given on a piece of apparatus by the individual manufacturers, there is an implied guarantee that the apparatus will have a reasonable life and that the design of the individual component parts of the piece of apparatus will be such that it will have a performance consistent with the other parts of the apparatus.

CONCLUSION

It is hoped that the foregoing discussion will clarify thought with regard to the nature and the effect of errors in the control system of feeder regulators. The transformer subcommittee at present is continuing the task of preparing a standard for the specification of accuracy tolerance and for the establishment of accuracy classifications. Provision will be made so that as improvements materialize the best accuracy consistent with cost can be incorporated.

It is suggested that distribution and transmission engineers, equipment application engineers, and others interested in system design and layout consider this matter as applied to their own systems. Comments relating to this subject should be directed to the chairman of the transformer subcommittee.

A Physical Conception of Single-Phase Motor Operation

ROBIN BEACH
FELLOW AIEE

Textbooks and other treatises that purport to explain the physical concepts of the operation of the single-phase induction motor by the cross-field theory do so mostly by employing simultaneously developed space-phase and vector diagrams. Unfortunately this method has not been found adequate nor of proper approach to provide an understanding of the physical reactions within the motor. The author has evolved a technique for presenting the basic concept of how the motor develops its torque and power by which he constructs, concurrently with the development of the space-phase diagram, the rotor voltage, current, and flux curves of the correlative time-phase diagram.

IN the development of the cross-field theory for the single-phase induction motor, a particularly favorable opportunity is provided to present a clear interpretation of how the stator and rotor fluxes and currents mutually interact to develop torque and maintain rotation. The mathematical relationships are presented in various textbooks and papers on the subject, but for the first study of the subject the mathematical treatise should be given secondary importance to that of conveying a clear understanding of the physical reactions of the electric and magnetic quantities within the motor.

In addition, a clear and logical treatment of the physical behavior of this motor affords a unique opportunity, coming as this subject does near the end of the course in a-c machines, to provide a comprehensive review of almost all the basic relationships applying to electrical machines. Such a critical retrospection of these principles serves admirably to re-emphasize, and to reorganize into more applicable form, the important fundamentals which are basic to both those static and rotating types of machines previously studied.

The types of systems employed to provide starting torque for single-phase induction motors and which modify the physical structures of the stator and rotor of this motor, as compared with the polyphase induction motor, will not be given consideration in this treatise, as that phase of the subject is irrelevant to this paper and the subject is treated adequately elsewhere.

BASIC PHYSICAL CONCEPTS

As shown by the cross-sectional view in Figure 1, the stator winding is so arranged that, when it is energized from the supply line, the magnetic field which it produces alternates cyclically along the vertical Y axis. Let us assume that the turns of the winding are so disposed in the slots of the stator core as to produce a sinusoidal space distribution of flux circumferentially around the air gap

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under the polar areas, and that with respect to time the flux also varies sinusoidally. Of the total magnetic field, a small part of it only—the leakage flux—encircles locally the stator inductors without crossing the air gap into the domain of the rotor. This leakage flux is considered to give rise to the leakage reactance voltage in the primary winding. The remainder of the magnetic field—the mutual flux ϕ_M—interlinks the rotor, as well as the stator, inductors.

In Figure 1, the motor is shown to contain the customary squirrel-cage rotor bars. These inductors on one side of the vertical plane which contains the rotor axis, the trace of which is Y–Y, could be considered paired at any instant with those on the other side of the vertical plane. This concept is shown in the simple conventional diagram of Figure 2.

The periodic variation of the mutual flux ϕ_M of the main field induces a transformer voltage both in the stator winding and in the rotor winding. In the stator winding, the vector difference of this transformer voltage and the impressed line voltage is the leakage impedance voltage, and it is proportional to the primary current. Its variation between no load and full load causes a small change in the magnitude of the mutual flux ϕ_M. But for the purpose of this qualitative presentation, the main field flux ϕ_M may be considered constant.

TRANSFORMER VOLTAGE INDUCED IN ROTOR BY MAIN FIELD

In the rotor winding, the transformer voltage, which is induced there by the alternations of the main field ϕ_M, is only one of several component voltages which are to be individually considered during the development of the cross-field theory. The amplitude of this induced voltage is determined by the magnitude of the mutual flux of the main field, by the frequency at which the flux alternates, and by the equivalent number of turns in the rotor winding. In time phase, the voltage is in lagging quadrature with the flux ϕ_M. This voltage causes currents in the closed rotor circuits, as shown by the paired inductors of Figure 2, for each of which the magnetic axis is perpendicular to the plane containing the paired inductors, and, in consequence, it is coincident in each case with the magnetic axis of the stator winding, the Y axis. And further, the induction of this transformer voltage is not influenced or modified by whether the rotor is stationary or in rotation.

When the rotor is in rotation, the successive inductors, as can be reasoned from the geometry of the squirrel-cage winding and shown in Figure 2, momentarily form new pairs as they pass through the vertical plane, the trace of which is the Y axis. On the basis of this hypothesis of how the rotor inductors, when in rotation, may be considered to form themselves continually into pairs distributed about the Y axis, the resulting magnetic axis for these pairs is maintained coincident at all times with the magnetic Y axis of the primary winding.

The transformer voltage induced in the rotor may be designated by appropriate subscripts to indicate that it results from transformer action, T; from the main field mutual flux, ϕ_M; and that it causes, through the current it produces in these paired rotor turns, a resultant magnetomotive force along the Y axis—the magnetic axis of the stator field. This voltage, E_{TMY}, then may be identified fully from the appended subscripts.

The magnetic effect along the Y axis produced from these paired rotor inductors carrying the rotor current I_Y, which results from E_{TMY}, is counterbalanced in the stator winding by an equal number of ampere-turns, and so if the equivalent number of turns in the rotor and in the stator are equal, then the rotor current has its exact counterpart in the primary. For the sake of simplicity let us assume unit transformation ratio throughout this presentation. These voltage, current, and magnetic effects

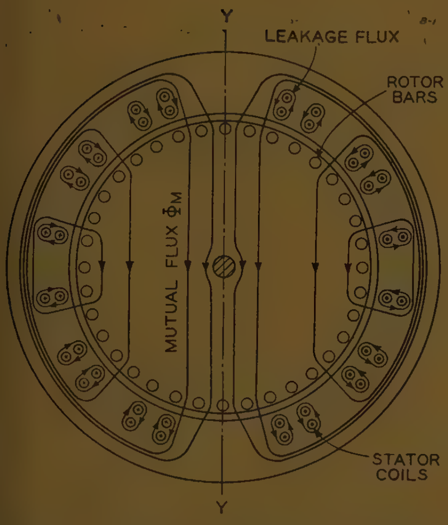

Figure 1. **The energized stator windings cause leakage fluxes about the stator conductors, mutual flux in the rotor, and induced voltages and currents in the rotor inductors. No torque is developed at standstill**

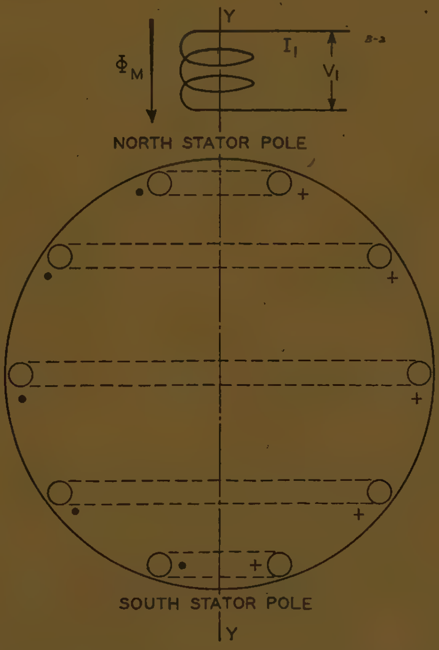

Figure 2. **The assumed pairing of squirrel-cage rotor bars about the Y axis helps to visualize the magnetic reaction of the rotor with the stator by transformer effect**

The voltage induction in the rotor bars is shown in the direction indicated by the dots and crosses for an increasing stator field

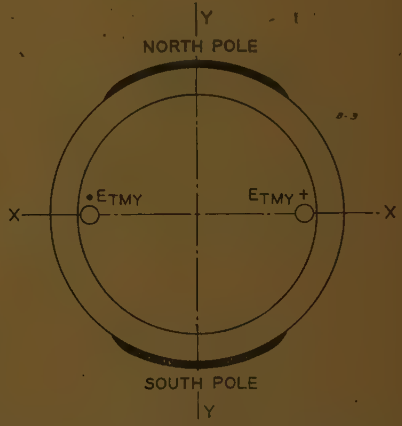

Figure 3. **A hypothetical equivalent coil replaces in effect the paired rotor inductors centered about the coaxial magnetic Y axis**

This concept is utilized to aid the visualization of the magnetic effects of the rotor windings and of the directions of induced voltages, currents, and fluxes in the motor, even when rotating, are precisely identical to those which occur in a transformer when its secondary winding is short-circuited. In order for the current in the rotor inductors to modify the stator current, as under a change in load, for instance, it must have its magnetic reaction along the Y axis, as Figure 2 shows it has, and thus magnetically interlink the stator winding. The greater the rotor current is, the greater the stator current must be in order to counterbalance it magnetically.

The direction of the induced voltage E_{TMY} and the direction of the dependent magnetic effect of its current through the resulting magnetomotive force are more simply represented by considering all of the paired inductors in Figure 2 to be replaced, for the particular instant being considered, by a coil of an equivalent number of turns and located in the horizontal plane through the rotor axis, so as to retain the same magnetic Y axis, as shown in Figure 3. This hypothetical equivalent coil of Figure 3 is properly labeled to show the identity of the voltage induced in it, and by means of the conventional dot or cross for the respective head or tail of an arrow, the direction of the induced voltage for a particular instant is indicated on the figure. The dots and crosses showing the instantaneous directions of all voltages in figures throughout this paper are placed outside of, but closely adjacent to, their respective inductors and then labeled with their identifying voltages.

In the development of the following presentation, one particular instant of time is assumed, although it will be observed later that the same terminal results obtain by the use of any other chosen instant. The instant of time to be considered is shown by the vertical line on the time-phase diagram, Figure 4, which is marked instant 1 at the bottom of the graph. At this instant the curve representing the stator main field, which is labeled ϕ_M (1), is increasing in magnitude, and the assumption is made that the upper stator pole in Figure 3 is of north polarity. The polar areas on the stator, as so produced by the impressed main field, are also shown in Figure 3, for clarity and emphasis, by the heavy circular arcs. The voltage E_{TMY} is shown on the time-phase diagram, Figure 4, as curve (2), having been drawn in quadrature lagging phase with respect to the stator field ϕ_M which induces it. Numbers in parentheses indicate the order of derivation, and coincidentally assist in reference.

With the polarity of the stator field assumed, as in Figure 3, and with ϕ_M increasing, as shown at instant 1 of Figure 4, the direction of the induced rotor voltage E_{TMY} is then determined by the application of Lenz's law. Its direction is such that its resulting magnetic effect along the Y axis opposes the *increase* of the stator field ϕ_M, and this direction is so indicated on the space-phase diagram, Figure 3, where the voltage is properly labeled with the dot and cross, as shown.

Thus, by the gradual development of the time-phase diagram, curve by curve, correlatively with that of the space-phase diagram, the interpretation of the theory of the motor is revealed step by step.

SPEED VOLTAGE GENERATED IN ROTOR BY MAIN FIELD

When the rotor inductors rotate through the main field ϕ_M, speed voltages are generated in one direction in all of those inductors which are, at the instant, above the horizontal plane, and voltages in the opposite direction are produced in the inductors occupying positions below the horizontal plane. These inductors, in which voltages are generated by their speed action through the main field, may also be regarded as paired, except that, in so doing, one above and a corresponding one below the X axis are considered to lie in a vertical plane, each pair with its magnetic axis individually coincident with the X axis, as shown in Figure 5.

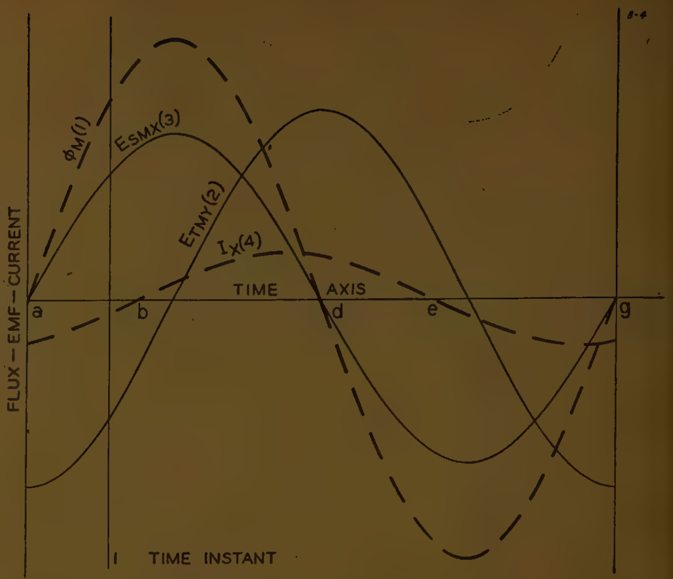

Figure 4. The time-phase diagram showing the rotor voltages and current which result from the transformer and speed action by the main stator field

This speed voltage E_{SMX} is identified by appending the subscripts S to imply speed action in its generation, M to indicate generation in the main field, and X for the X axis along which the coils exert their magnetomotive force. The voltage E_{SMX} is generated by, and is in time-phase with, the main field flux ϕ_M, and on the time-phase diagram, Figure 4, this voltage is so drawn, as curve (3). If the motor is assumed to be operating under load, it then has an appreciable slip, and hence the speed voltage E_{SMX} is less in magnitude than the transformer voltage E_{TMY} of curve (2) by the proportion that the speed is less than synchronous. The transformer voltage is, of course, independent of speed. Should the motor be run at synchronous speed, by driving it, the speed voltage E_{SMX} would then be equal to the induced voltage E_{TMY}.

The currents in the paired inductors, which result from the speed voltages, produce their magnetomotive forces,

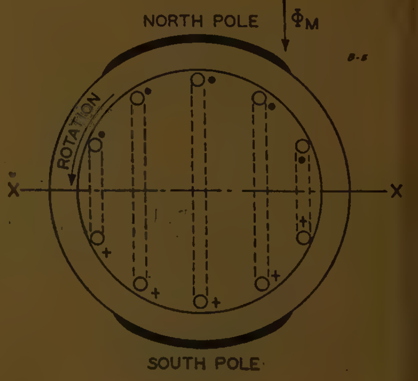

Figure 5. The direction is shown for the speed voltage E_{SMX} as generated in the paired inductors of the squirrel-cage winding under the given conditions of polarity and direction of rotation

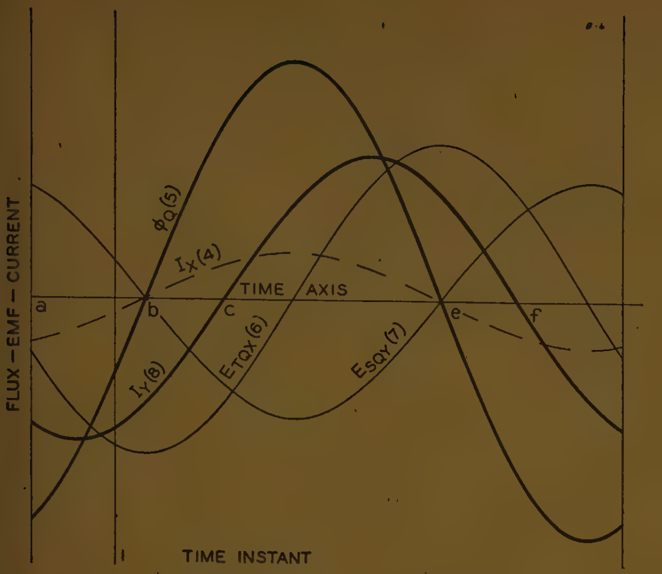

Figure 6. The time-phase diagram showing the rotor voltages and currents which result from the transformer and speed action by the quadrature field

and, hence, their resultant field, ϕ_Q, along the X axis, and accordingly this field lies in exact space quadrature at all times with the main field ϕ_M. By reason of this quadrasure field, the name "cross-field" theory is derived. Because these paired inductors possess the traits of an iron-core reactor, with no other winding upon which their resultant flux can react and thereby lower their impedance, this exciting current I_X of the rotor, that results from the speed voltage, lags E_{SMX} in time phase by nearly 90 electrical degrees. In magnitude this exciting current I_X, which causes the quadrature field ϕ_Q and which for linear magnetization is about proportional to the rotor speed, is slightly less than the exciting current for the stator field—a quantity which is assumed in this presentation to be independent of speed and hence, to be constant. This stator exciting current is not included on Figure 4, but the rotor exciting, or quadrature field, current I_X is shown as curve (4), and it is drawn to lag E_{SMX} which causes it by a large phase angle, as may be observed from the time-phase diagram.

In the interests of simplicity, the quadrature field ϕ_Q is considered here as being proportional to and in time-phase with the rotor exciting current I_X rather than being in phase with the magnetizing component of the exciting current, a current which lags I_X by a small angle and which lags E_{SMX} by 90 electrical degrees. The quadrature field ϕ_Q is so drawn in phase with the exciting current I_X—the latter having been redrawn for orientation—in Figure 6 wherein the field flux is shown as curve (5). Also at a particular instant, the quadrature flux ϕ_Q may be regarded as being caused by the magnetomotive force of the field current I_X in an equivalent hypothetical coil which replaces in effect the magnetomotive forces of all the paired inductors on the rotor, as shown in Figure 5, and which have their magnetic axes coincident with the X axis. This equivalent hypothetical coil is shown in Figure 7, and for the instant 1 when the upper main pole is of north polarity, and for a counterclockwise direction of rotation, the direction of the generated speed voltage E_{SMX} in this coil is also shown.

POLARITY OF THE QUADRATURE FIELD

Before being able to proceed with the development of the theory, the polarity of the quadrature field at instant 1 must be determined. Since the direction at a particular instant of the exciting current I_X in the rotor windings determines the direction of the quadrature field, this essential information is obtained by reference to the time-phase diagram of Figure 4. Because of the large phase angle of the rotor cross-field current I_X behind the speed voltage E_{SMX} which causes it, its polarity at instant 1 is seen from Figure 4 to be oppositely directed to E_{SMX}. Thus, in Figure 7, the exciting current I_X is shown inward for the inductors at the top of the equivalent coil and outward at the bottom—the dots and crosses, representing current, being placed within the inductors.

A current in this direction in the rotor bars causes its field—the quadrature field ϕ_Q—to form a north polar surface in the stator at the right and a south polar surface at the left. The polar areas formed at the surface of the stator core both for the main and quadrature fields are indicated by the heavy circular arcs in Figure 7. The quadrature poles thus formed by the magnetomotive force of the exciting current I_X within the rotor bars are represented by the heavy dashed lines as a means of differentiating them from the main poles which are produced by the magnetomotive force of the stator winding. Since the quadrature field comes into being as the result of the speed voltage E_{SMX} and its dependent current I_X, it is not present when the rotor is at standstill—and hence the dashed-line construction to represent its polar areas.

TRANSFORMER VOLTAGE INDUCED IN ROTOR BY QUADRATURE FIELD

An inspection of Figure 6 shows the curve of the quadrature field ϕ_Q (5) to be decreasing toward zero at instant 1, and, because of this, transformer voltages are being induced in the same group of rotor inductors in which speed voltages from the main field ϕ_M are being generated, that is, in those inductors coaxially paired about the X axis, as shown in Figure 5. By the application of Lenz's law again, the induction is found to be in such a direction as to tend to sustain the decreasing quadrature field, and thus these induced voltages are seen to be oppositely directed to those generated by speed action from the main field. The voltages are inward for the inductors above the X axis and outward below.

The polarity of the voltage induction is shown in Figure 7 by the dot and cross associated with the voltage E_{TQX}. Here the subscripts have the following designation: T signifying transformer action in the coils by virtue of the variation of the cross field ϕ_Q, and X indicating the X axis along which is directed the resultant magnetic action of the rotor coils that are coaxially disposed about the X axis. Only currents are shown in their momentary directions by appropriate dots and crosses placed within the conductors, while all voltages have their directions indicated by dots and crosses placed outside of, but near, the conductors, and properly labeled with their associated voltages.

The transformer voltage E_{TQX} which is induced by the quadrature field ϕ_Q lags the flux by 90 electrical degrees. The magnitude of E_{TQX} is almost equal to that of the speed voltage E_{SMX}, being less only by the vector difference of the rotor leakage impedance voltage which results from the small rotor current I_X. On the time-phase diagram, Figure 6, this transformer voltage E_{TQX} is drawn as curve (6), in lagging quadrature with the flux ϕ_Q, and in magnitude a little less than that of E_{SMX}. Because these two voltage curves are not quite in phase opposition, the value of E_{TQX} at instant 1 is slightly greater than the value of E_{SMX}, a fact which accounts for the rotor exciting current I_X being momentarily in the direction opposite to E_{SMX}, as previously described and as shown in Figure 7.

SPEED VOLTAGE GENERATED IN ROTOR BY QUADRATURE FIELD

With the polarity of the quadrature poles corresponding to the conditions of instant 1, as shown in Figure 8, and for counterclockwise direction of rotation, speed voltages are generated in those inductors which are under the influence of the quadrature poles and which inductors are considered as being paired coaxially about the Y axis. These are the same paired inductors which are shown in Figure 2 as having induced in them the transformer voltage E_{TMY} from the main field ϕ_M. The direction of the speed voltage E_{SQY} is found to be outward in the inductors to the right of the Y axis under the north pole and inward for those at the left under the south pole—directions which are observed to be opposite to those for the transformer voltage E_{TMY}.

In placing the curve for the speed voltage E_{SQY} on the time-phase diagram, Figure 6, it is to be drawn either in time phase with the quadrature field ϕ_Q from which it is generated or in time-phase opposition to it, in which latter case the speed voltage would appear as a countervoltage in the rotor. The information for determining in which of these two positions with respect to the quadrature field the speed voltage E_{SQY} is to be drawn appears from the fact already established, namely that the direction of the speed voltage E_{SQY} is opposite to that of the transformer voltage E_{TMY}. Reference to the time-phase diagram, Figure 4, shows the direction of the transformer voltage E_{TMY} (2) at instant 1 to be the same as the quadrature field ϕ_Q (5), Figure 6, that is, both are negatively directed. So, therefore, the speed voltage E_{SQY}, being of opposite direction to E_{TMY}, as shown by Figure 8, is drawn in time-phase opposition to the quadrature field ϕ_Q which causes it. Before the speed voltage E_{SQY} can be drawn as a curve on Figure 6, its maximum value must be determined.

Since the transformer voltage E_{TMY} and the speed voltage E_{SQY} appear as oppositely directed voltage components in the same group of rotor inductors, Figure 8, their vector difference is then the unbalanced leakage impedance voltage drop which causes the load current I_Y in those inductors coaxially grouped about the Y axis. The transformer voltage E_{TMY}, being induced by the assumed constant main field ϕ_M, is independent of speed, and, hence, it is the largest voltage component in the rotor. The speed voltage E_{SQY} is the smallest.

This speed voltage E_{SQY} is smallest because it is dependent upon the magnitude of the quadrature field, which is less than that of the main field by the approximate value of the rotor speed compared with that of the synchronous speed, and also it is dependent upon the speed of cutting the quadrature field which is likewise less than the synchronous speed. In other words, the speed voltage E_{SQY} is about proportional to the square of the rotor speed. To illustrate this numerically, assume the rotor speed is 90 per cent of the synchronous speed, then the speed voltage E_{SQY} is about 81 per cent of the value of the transformer voltage E_{TMY}, or about 19 per cent less in value.

Thus, in Figure 6, the curve of the speed voltage appears as E_{SQY} (7), drawn in time-phase opposition to the quadrature field ϕ_Q (5) and to a magnitude less, by the approximate ratio of rotor speed to synchronous speed, than E_{TQX} and considerably less than E_{TMY}—less by the square of the above ratio of speeds. Because of the phase difference between the speed voltage E_{SQY} and the transformer voltage E_{TMY}, the transformer voltage E_{TMY} at instant 1 is seen from Figure 4 to be of large magnitude and of opposite direction compared to that of the speed voltage E_{SQY}, Figure 6. The difference in voltage between them is the leakage impedance voltage at this instant and it is obviously large. As the leakage impedance of the rotor winding is the same along any axis of the rotor because of its electric and magnetic symmetry, this large leakage impedance voltage results from a large load current I_Y in the rotor, as the impedance itself is relatively small.

THE LOAD CURRENT I_Y OF THE ROTOR

The load current I_Y in those equivalent rotor inductors, as shown in the hypothetical coil of Figure 8, is caused by the transformer voltage E_{TMY}, and the magnitude of the current is so controlled by the countervoltage E_{SQY} as to accommodate itself to variations in the load. As the load on the motor increases, the speed decreases and with it the speed voltage E_{SQY} decreases. Thus with decreasing speed the vector voltage difference between the constant voltage E_{TMY} and the variable speed voltage E_{SQY} increases, and in proportion to it, the load current I_Y increases and simultaneously improves its power factor with respect to E_{TMY}. This load current I_Y is shown in suitable magnitude and phase in Figure 6 as curve (8). It lags E_{TMY} by a small angle for heavy load and by a large angle for light load.

In the final analysis, the correct magnitude and phase of I_Y, as well as of some of the other quantities, can be determined only by the simultaneous solution of three basic equations which contain and interrelate the stator input current I_1, the rotor exciting current I_X, and the rotor power current I_Y. This information expressing the exact quantitative values is not necessary to this qualitative explanation of the physical operation of the motor. Further details may be found in references 1 and 2.

DEVELOPMENT OF MOTOR AND GENERATOR TORQUES

The complete space-phase diagram for instant 1 and for the assumed direction of rotation consists of the superposition of Figure 7 and Figure 8. This composite diagram is represented by Figure 9 except that, in the interests of clarity, all voltages and their directions are omitted, as they were only incidental to determining the directions of the currents I_X and I_Y and of the quadrature field ϕ_Q—all at instant 1. The dots and crosses within the conductors indicate here, as in all previous diagrams, the directions of the currents.

An inspection of Figure 9 divulges the essential information that (1) the quadrature field current I_X exists in those inductors which lie under the main poles, and

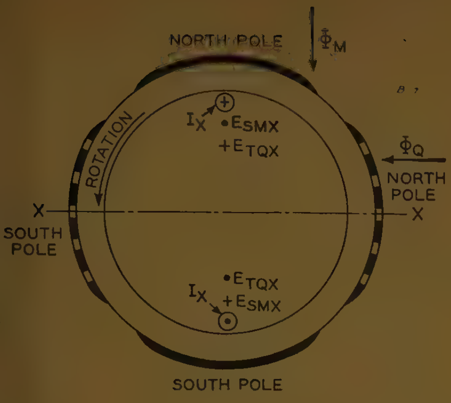

Figure 7. A hypothetical coil equivalent to the squirrel-cage winding in magnetic effect along the *X* axis, showing at instant 1 of the time-phase diagram the directions of the speed voltage E_{SMX}, the exciting current I_X, the quadrature field ϕ_Q, and the transformer voltage E_{TQX}

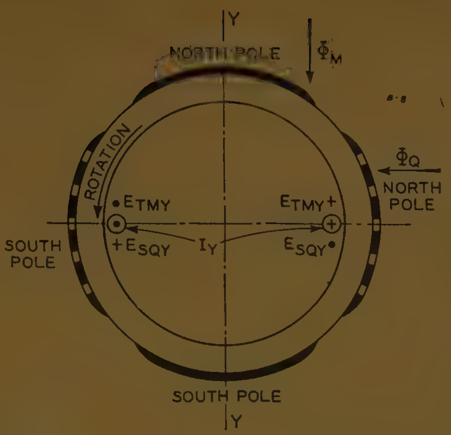

Figure 8. A hypothetical coil equivalent to the squirrel-cage winding in magnetic effect along the *Y* axis, showing the directions of the transformer voltage E_{TMY}, the speed voltage E_{SQY}, and the load current I_Y, all at instant 1 of the time-phase diagram

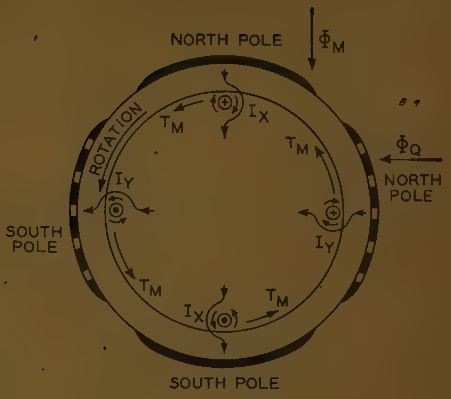

Figure 9. The composite space-phase diagram showing the directions of the rotor currents, fluxes, and resulting torques in the equivalent rotor coils for instant 1 of the time-phase diagram

(2) the load current I_Y is in those inductors which lie under the quadrature poles. This is true at all times, and hence these current-carrying inductors for currents I_X and I_Y develop torque with their respective main and quadrature fields. The directions and the relative magnitudes of the torque for both assumed groupings of inductors, at instant 1, are shown by the arrows labeled T_M. If the developed torque is exerted in the direction of the rotation, it is motor torque, otherwise it is generator torque. Its magnitude depends upon both the strength of the field and the value of the current at a given instant, and hence upon their product, as $\phi_M \times I_X$ and $\phi_Q \times I_Y$.

THE AVERAGE MOTOR TORQUE

Since both of these current-flux reactions are seen from Figure 9 to develop motor torque at instant 1, they may both be plotted on a time-phase diagram either upward or downward, as desired. In order to provide ultimately a time-phase diagram of the torque curves, free from the distracting complication of unessential curves, each flux curve with its torque-producing current curve have been reproduced from Figure 4 and Figure 6 onto Figure 10. The motor torque was arbitrarily assumed in the upward direction—above the time axis. At instant 1 the magnitudes of both the quadrature field ϕ_Q and the load current I_Y are seen to be of considerable proportions with respect to their maxima, and thus the motor torque which is proportional to their product $\phi_Q \times I_Y$ is of considerable magnitude. For other instants of time from instant 1 toward the origin at instant *a*, the magnitude of the quadrature field ϕ_Q increases more than two-fold, while that of the load current I_Y changes very little, and hence the motor torque $\phi_Q \times I_Y$, instant by instant, increases to its maximum value, as shown to be attained at about instant *a*. From this maximum, for successive instants of time to instant *b*, the value of torque—$\phi_Q \times I_Y$ (9) decreases to zero, at which instant the quadrature field ϕ_Q is zero.

As the quadrature field ϕ_Q reverses its polarity, the conductors under these reversed poles, which are still carrying the load current I_Y (8) in the same direction as before, now develop reversed torque, that is, generator torque. This is drawn as such in the reversed direction, and it is so shown on Figure 10, from instant *b* to instant *c*. At instant *c* the load current I_Y becomes zero and, in consequence, the generator torque $\phi_Q \times I_Y$ reduces to zero. Between the time interval *c* to *e* the current I_Y is in a direction reversed to that existing from instant *a* to instant *c*, thus reversing the direction of the torque $\phi_Q \times I_Y$, and hence changing it from generator, back again, to motor torque. At instant *e*, the field ϕ_Q reverses and, hence, the torque is reversed so that generator torque is developed thereafter from instant *e* to instant *f*. At instant *f* the current I_Y reverses, and thus the torque is again reversed, motor torque being developed from instant *f* to instant *g*—thus completing the cycle.

The torque $\phi_Q \times I_Y$ is seen to be predominantly motor

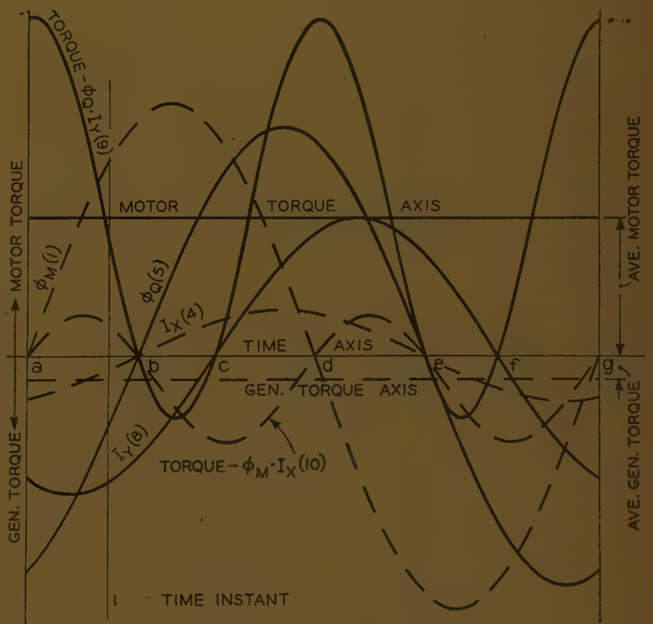

Figure 10. The time-phase diagram showing the development of motor and generator torques resulting from the quadrature field and power currents in the rotor reacting with the stator and quadrature fields, respectively

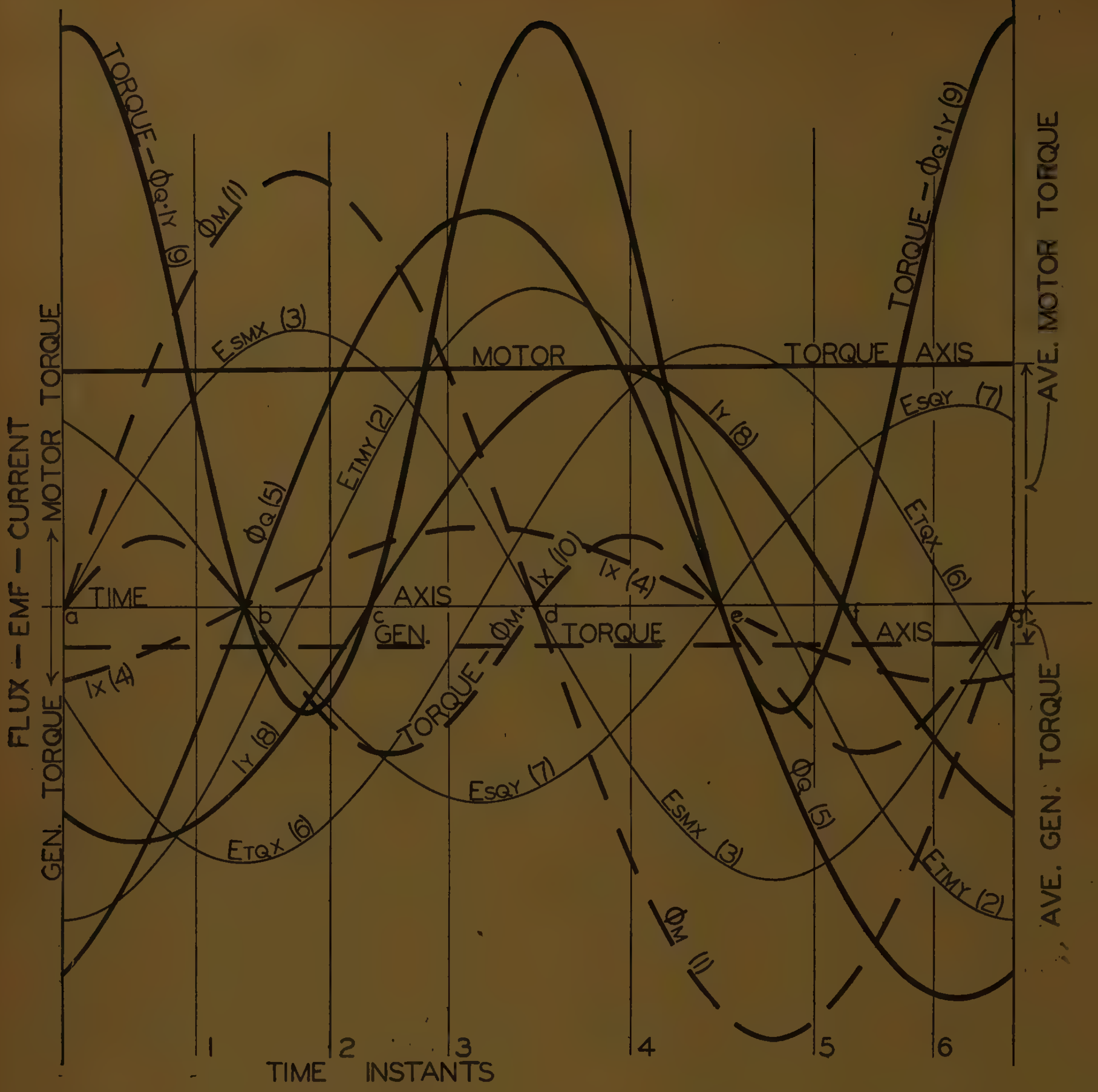

Figure 11. The complete time-phase diagram

The numbers on the curves indicate their order of explanation in the text and their order of development on the diagram, as well as serving as identification for reference

torque throughout a cycle of flux and current variation, as shown by curve (9). The average value of motor torque is found by obtaining the difference of the positive and negative areas, say in square-inch units, as taken between curve (9) and the time axis, and dividing this net area by the length of the base line from *a* to *g*, expressed in inches. This result in inches plotted vertically upward from the time axis locates the position of the motor-torque axis, and when translated into torque units, as were employed in plotting the torque curve, the distance of this new and displaced axis above the time axis represents the average motor torque. The value of the average motor torque is proportional to the product $\phi_Q \times I_Y \times \cos \theta_{I_Y}^{\phi_Q}$. For this instantaneous or average motor torque to attain a maximum for a given magnitude of ϕ_Q and I_Y, two conditions of phase relationship are necessary. These are: (1) that quadrature space phase exist between the axis of the flux and the axis of the magnetomotive force of the current; and (2) that the time phase between the flux and the current be zero. The first requirement for optimum torque is completely satisfied at every instant in the single-phase induction motor, and the second is dependent upon the value of the cosine of the angle between the flux and current—which is a function of the load on the motor.

A much simpler construction for the motor-torque axis is to draw it as an axis of symmetry midway between the maxima of the torque curve $\phi_Q \times I_Y$ (9). With respect to this axis, the torque is seen to possess a double-frequency variation, developing principally motor torque whereby electrical power from the supply is transformed into mechanical power through the driving torque for the motor, but for short intervals of time, as between *b* and *c* and *e* and *f*, the rotor, in creating generator torque, yields electrical power to the electrical supply system.

THE AVERAGE GENERATOR TORQUE

Under the main poles the current-carrying conductors in which the quadrature field current I_X exists, as shown in the space-phase diagram, Figure 9, develop torque with the main field ϕ_M. As explained earlier, this torque at instant 1 was found to be motor torque. It is so plotted on Figure 10 for instant 1; and, the instantaneous products of the main field ϕ_M and the quadrature field current I_X throughout a cycle give curve (10) which is labeled "Torque—$\phi_M \times I_X$ (10)." The torque $\phi_M \times I_X$ becomes zero at the origin, instant *a*, when ϕ_M is zero, and it likewise becomes zero to the right of instant 1 at *b* when I_X is zero, as is apparent from an inspection of Figure 10. Between instants *a* and *b* this torque is proportional to the instantaneous value of the product of ϕ_M and I_X, and it is of relatively small magnitude when compared to the main torque $\phi_Q \times I_Y$ for two reasons: (1) the quadrature field current I_X is small in comparison to I_Y, and (2) it lags ϕ_M by such a large time-phase angle that little average torque is developed.

The torque resulting from the reaction of ϕ_M and I_X changes from motor torque to generator torque at instant *b*, and it is generator torque between *b* and *d*, on Figure 10, because of the fact that the current I_X reverses its direction at *b*. The generator torque is represented in the downward direction, by adopted convention, between *b* and *d*. The area between this torque curve, $\phi_M \times I_X$ (10), and the datum time axis from *b* to *d* is obviously considerably greater than that under the same torque curve between *a* and *b*. At *d* the main field ϕ_M is seen to reverse polarity, the direction of the current I_X remaining unchanged, and thus the torque $\phi_M \times I_X$ reverses from its previous generator torque back to motor torque again. And later at *e*, the current I_X changes direction, and thus the torque changes again and becomes generator torque, remaining so between the time intervals *e* and *g*.

By following this torque curve $\phi_M \times I_X$ (10) throughout a cycle from *a* to *g*, it is seen to possess (1) a double-frequency variation, (2) an average value of generator torque, as the areas between the torque curve and the time axis are greater for generator action—*b* to *d* and *e* to *g*—than for those representing motor action—*a* to *b* and *d* to *e*, and (3) sine-wave symmetry about a displaced axis—the generator-torque axis—which is drawn midway between the maxima of the curve and whose displacement below the time axis is the measure of the average generator torque.

The composite and completed time-phase diagram showing the many correlated curves of fluxes, voltages, and currents for the rotor, as already presented by family groups in Figures 4, 6, and 10, is included here for reference as Figure 11. The four subordinate voltage curves are shown as light-weight lines, whereas the curves for ϕ_Q (5) and I_Y (8) and their product, the torque curve $\phi_Q \times I_Y$ (9), are drawn as heavy solid lines, and the curves for ϕ_M (1) and I_X (4) and their product, the torque curve $\phi_M \times I_X$ (10) are constructed as heavy dashed lines.

The instantaneous torques $\phi_Q \times I_Y$ and $\phi_M \times I_X$ may be independently determined at any other instants of time, as, for example, those shown as instants 2, 3, 4, 5, or 6 on Figure 11. The values of torque so determined obviously must be identical to those which have already been determined, that is, curves (9) and (10). The curves of flux, voltage, and current, in magnitude and in phase, when constructed for any other instant of time, will be found to be identical to those of Figure 11 regardless of the instant of time employed for their determination.

THE ROTOR CORE LOSS

The magnitude of the average generator torque is determined by the product of the in-phase component of the quadrature field exciting current I_X with the main field ϕ_M with which it reacts. If I_X should lag ϕ_M by 90 electrical degrees, then the torque curve $\phi_M \times I_X$ (10) would be disposed about the time axis so as to have equal areas representing motor and generator torque, and the average torque would be zero. Also, if the exciting current I_X were in lagging quadrature with ϕ_M and hence with E_{SMX} which produces it, it would develop zero average generator power with respect to E_{SMX}, as an inspection of Figure 11 substantiates. In this hypothetical case, there could be no iron losses in the rotor core resulting from the quadrature field.

Actually the current I_X is not quite in lagging quadrature phase with its speed voltage E_{SMX}, and thus it develops an average generator power just sufficient to supply the rotor core loss that results from the quadrature field. The average generator torque, as shown on Figure 11, at rotor speed, develops just the proper value of mechanical power to cause the rotor core loss to be supplied electrically. Since the quadrature field ϕ_Q is assumed to vary linearly with its field current I_X, then the rotor core loss, which is caused by it, decreases as a function of the increasing load on the motor, that is, an increasing load causes the speed to decrease, and with it E_{SMX}, I_X, ϕ_Q, and the rotor core loss all decrease.

Since the quadrature field ϕ_Q, as shown by Figure 7, has no net induction with the primary or any other winding, the question arises as to how the power necessary to supply this rotor core loss, resulting from the quadrature flux, is caused to flow into the motor. Because of the fact that this rotor core loss is supplied by the power generated within the rotor and developed by the average generator torque at the rotor speed, a small mechanical load is imposed upon the rotor as a result of it, and, hence, the motor runs at a slightly lower speed than it would if this loss did not exist. This reduction in speed causes the load current I_Y of the rotor to increase slightly and it is this current which reacts through its magnetomotive force on the stator windings. It causes an increment of input current into the stator winding, and together with a small improvement in its phase, it is just sufficient in magnitude to supply electrically the power for the rotor core loss.

For this reason, the speed of the single-phase motor at no load and under a hypothetical condition of zero friction and windage losses would be slightly below the synchronous value and by an amount just necessary to cause the rotor core loss to be supplied through the reflected load component of the power current I_Y in the stator winding. Under these same assumptions of no load and zero mechanical losses for the polyphase induction motor, it would run at exactly synchronous speed.

THE VECTOR DIAGRAM AND ITS ANALYSIS

Finally, the vector diagram is presented as a visual aid in showing the magnitudes and the phase relationships of the electric and magnetic quantities within the motor. The approximate vector diagram for the single-phase induction motor is shown in Figure 12. All quantities which occur in the stator winding are so designated by attaching to their symbols either a prime (′) or a subscript ($_1$), otherwise the quantities are those occurring in the rotor. The symbols, together with their identifying subscripts, have already been explained, with the two exceptions of E_X and E_Y. The vector difference of the two voltage components E_{SMX} and E_{TQX} in those rotor inductors which are considered paired about the *X* axis, as their magnetic axis, is the leakage impedance voltage E_X. Likewise for those inductors paired about the *Y* axis, the vector difference of the two voltage components E_{TMY} and E_{SQY} is the leakage impedance voltage E_Y.

In this vector diagram as in the time-phase diagram of Figure 6, the quadrature field ϕ_Q has been drawn in phase with the exciting current I_X rather than in phase with its magnetizing component which lags I_X by a small angle. By this simplification, unnecessary confusion of both diagrams is avoided; and, for the purpose of qualitative analysis, the variation with speed of the factors which determine the development of the motor and generator torques and power becomes more readily apparent.

As already explained, the components of leakage impedance of the rotor along the X axis are equal, respectively, to those along the Y axis, and hence the magnitude of either one of these impedance voltages depends upon the magnitude of the current causing it. The quadrature field exciting current I_X is slightly less than the exciting current I'_N for the stator field ϕ_M, and their ratio is equal to the ratio of ϕ_Q to ϕ_M. The current I_X lags the voltage E_X by the characteristic angle of the leakage impedance—an angle equal to that by which the load current I_Y lags its impedance voltage E_Y. Still assuming a linear magnetization curve, the load current I_Y varies proportionately with I_X as E_Y varies with E_X.

Since the stator field ϕ_M is considered constant, the quantities E_{SMX}, I_X, ϕ_Q, E_{TQX}, and E_X all vary in proportion to the speed. Hence as the speed of the rotor falls off with increasing load, both E_{SMX} and E_{TQX} decrease proportionately with the speed, and so then does the quadrature field current I_X and its field ϕ_Q. It should be observed that E_{TQX} is less than E_{SMX} at all speeds, including synchronous speed, by the amount of the vector difference of the leakage impedance voltage E_X. The average generator torque, $\phi_M \times I_X \times \cos\theta_{I_X}{}^{\phi_M}$, decreases with the speed, and hence its developed mechanical power, which is the product of the torque and speed, decreases about as the square of the speed. This developed power is electrically the product of the in-phase component of the current I_X with its speed voltage E_{SMX}, a quantity which is also seen to vary about as the square of the speed.

The voltage E_{TMY}, which corresponds to the induced voltage E_2 in the secondary winding of a transformer, is independent of speed, but the countervoltage E_{SQY} varies about as the square of the speed. For decreasing values of rotor speed, the load current I_Y increases at a rate almost inversely proportional to the square of the speed—a relationship which is apparent from an inspection of the vector diagram, because the vector difference of E_{TMY} and E_{SQY} is roughly approximate, numerically, to their arithmetic difference. The average motor torque, $\phi_Q \times I_Y \times \cos\theta_{I_Y}{}^{\phi_Q}$, increases for decreasing rotor speed for two reasons: (1) the load current I_Y increases more rapidly than the field ϕ_Q decreases with speed, and (2) the angle between ϕ_Q and I_Y decreases very appreciably with decreasing speed, thereby improving the power factor of the current. It is largely because of the latter effect that the developed motor power, which is the product of the average motor torque and speed, actually increases as the rotor speed decreases. This developed motor power may be expressed also as $E_{SQY} \times I_Y \times \cos\theta_{I_Y}{}^{E_{SQY}}$, and so in this case the developed power increases for decreasing speed, largely because of the increased power factor, despite the fact that E_{SQY} decreases about as the square of the speed and I_Y increases, roughly, as the square of the speed.

This presentation has demonstrated the fact that, in the process of developing the cross-field theory of the single-phase induction motor, the concurrent construction of two fundamental diagrams is essential, namely, the space-phase diagram, Figure 9, including the transformer and speed voltages, and step by step with it, the time-phase diagram, Figure 11. While the vector diagram is a desirable visual aid to the final analysis of the magnitudes of the average generator and average motor torques and developed power, yet in the interests of clarity of presentation, the vector diagram should not be employed as a substitute for the time-phase diagram in attemping to explain the interactions of the fluxes and currents within the rotor.

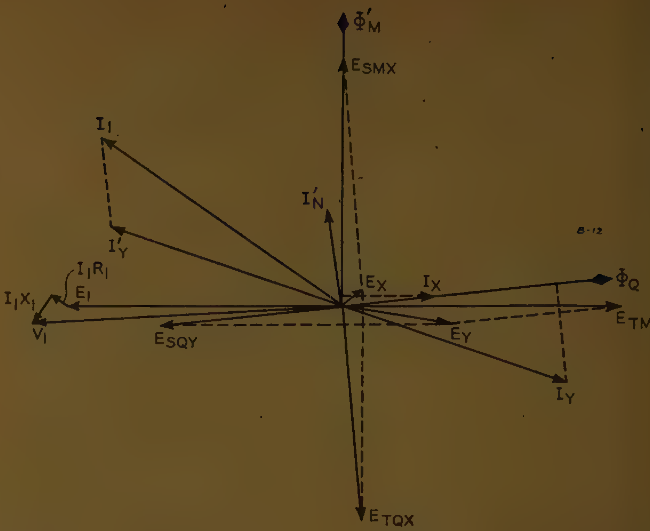

Figure 12. The time-phase vector diagram shows stator and rotor quantities

The positive projection of the quadrature field current I_X on its speed voltage E_{SMX} shows developed generator power to supply the rotor core loss, and the negative projection of the power current I_Y on its speed voltage E_{SQY} shows developed motor power

For simplicity of representation, the quadrature field ϕ_Q is shown in phase with the exciting current I_X, rather than lagging it by the characteristic hysteretic angle

SUMMARY

In order to leave with the reader a critical appraisal of the correlated electric and magnetic quantities within the single-phase induction motor, the coexisting reactions of the magnetic fields, the voltages, and the currents are recapitulated here in simple form for final review.

1. The main field of the motor is created by the magnetomotive force developed within the stator winding by the magnetizing component of the stator current. Except for the relatively small changes in the magnitude of the main field which occur as the result of variations of the stator leakage impedance voltage with changing loads, the main field may be considered as reasonably constant—at least so for the purposes of this qualitative presentation.

2. Recognizing these minor variations in the main field, for the reasons as explained above, it may for all practical purposes be considered constant and, hence, independent of the variations in the speed of the motor. The stator field comes into being at the starting of the motor, but it, alone, develops no starting torque in reacting with the closed windings of the rotor. Actually to develop starting torque, the motor requires the addition of some form of auxiliary starting circuit and, in certain instances, associated mechanisms.

3. The main field causes three voltages to be developed, two by transformer action and one by speed action. One of the transformer voltages is induced in the stator winding. It is proportional to the mutual value of the stator field and to the equivalent number of turns in the stator winding; and, acting as a counter electromotive force to the applied voltage, this transformer voltage controls the

magnitude of the input current to the stator winding. The vector difference of the line voltage and this induced voltage is the stator leakage impedance voltage, as already mentioned.

4. The other voltages which are developed by the main field, another transformer voltage and the speed voltage, are established within the rotor windings.

5. The transformer voltage in the rotor has been identified throughout the text as E_{TMY}, and its magnitude is also proportional to the mutual value of the main field, as well as to the equivalent number of turns in the rotor winding. This is the largest of four voltages which are developed in the rotor windings, and its value is independent of speed to the same extent as is the main field which induces it. This voltage gives rise directly to the load current I_Y in the rotor, and this is the only component of current in the rotor which can interlink with and react upon the energized windings of the stator.

6. This voltage E_{TMY} and its component current I_Y are present in the rotor, when the stator winding is energized, whether the rotor is in rotation or not. At standstill, the load current causes no torque to be developed for the reason that its magnetic reaction with the main field lies in exact space phase with it, just as occurs in a transformer whose secondary winding is short-circuited.

7. As rotation occurs, a field is developed by the rotor winding which is in space quadrature and practically in time quadrature with the main field. This quadrature field causes the formation of poles on the stator whereby the rotor load current I_Y, reacting with this field, produces the driving torque of the motor.

8. The speed voltage generated in the rotor winding from the main field, when rotation occurs, is identified throughout the text as E_{SMX}. This voltage varies directly with the speed, being zero at standstill and a maximum at synchronous speed, and it is nearly equal in this latter case to the transformer voltage E_{TMY}. This speed voltage causes a magnetizing current I_X in the rotor winding which, in turn, brings into being the quadrature field.

9. The quadrature field alternates at line frequency, as does also the main field, but, assuming the magnetic structure to be operated on the linear part of the saturation curve, the magnitude of the quadrature field depends directly upon the value of the rotor speed, being zero at standstill and about equal to the main field at synchronous speed. By reason of its dependence upon the speed, this field could be called, and appropriately so, the "speed field."

10. As in the case of the main field, so does the quadrature field develop two voltages in the rotor winding—both counter voltages, one being a transformer voltage and the other a speed voltage. The transformer voltage, which is identified throughout the text as E_{TQX}, is induced in the same conductors as the speed voltage of the main field E_{SMX}, and, in consequence, it controls the magnitude of the quadrature field current I_X. The speed voltage, which is identified throughout the text as E_{SQY}, is generated in the same rotor conductors as the transformer voltage of the main field E_{TMY}, and hence, it controls the magnitude of the load current I_Y of the rotor.

11. The magnetizing current I_X is in those conductors which lie under the influence of the main field, and it develops torque with the main field which is found to be predominantly generator torque. This torque alternates at twice the line frequency and its graph is disposed symmetrically about a displaced torque axis which lies parallel to the time axis and which is drawn midway between its maxima and minima values. Its displacement from the time axis is proportional to the average generator torque. The torque curve, therefore, consists of a constant component—the average generator torque—and a superposed symmetrical double-frequency component.

12. The load produced by this average generator torque causes the motor to run at a speed slightly lower than it would otherwise do if this torque were not present. Because of this idiosyncrasy of the single-phase induction motor, the generator action, through the increased value of the load current I_Y, reflects itself into the stator circuit, and by this reaction, a small increment of input power, which is required to supply it, flows into the motor from the service mains.

13. The average generator torque, acting at rotor speed, develops mechanically the necessary power to supply the core loss of the rotor, a loss which occurs within the magnetic core of the rotor because of the flux variations of the quadrature field. As just stated, this power loss is supplied electrically from the service mains to the motor by the reaction of the reflected counter magnetomotive force of the increased load current I_Y.

14. Since the average generator torque is a direct function of the speed and since the power necessary to supply the rotor core loss varies both with the generator torque and with the speed, the rotor core loss varies about as the square of the speed. Hence, the rotor core loss, resulting from the quadrature field, is a maximum at synchronous speed and as the speed reduces, it decreases rapidly—a condition which is just opposite to that for the rotor core loss of the polyphase motor.

15. The load current I_Y, being in those conductors under the influence of the quadrature field, develops predominantly motor torque. This torque also alternates at double line frequency, and its graph is symmetrically disposed about a displaced torque axis which is drawn parallel to the time axis, and on the opposite side of the time axis from the average generator torque, so that it lies midway between the maxima and minima values of the motor-torque curve. Its displacement from the time axis is proportional to the average motor torque. This torque curve, like that for the generator torque, consists of a constant component and a double frequency component.

16. The value of the average motor torque depends upon the magnitude of the quadrature field, the value of the load current I_Y, and the cosine of the angle between them. The magnitude of the quadrature field varies about directly with the rotor speed. The load current, depending as it does upon the vector difference of the constant voltage E_{TMY} and the speed voltage E_{SQY}, which latter voltage is about proportional to the square of the speed, varies almost as the inverse square of the speed. The value of the cosine of the angle between the quadrature field and the load current increases very considerably with decreasing speed. From these variations, it can be seen that the average motor torque, within the normal operating range of the motor, increases, roughly, at a linear rate with decreasing speed.

17. The developed power of the motor, being proportional to the product of the load current I_Y, the speed voltage E_{SQY}, and the cosine of the angle between them, increases as the speed decreases, and this increase of developed power occurs largely through the improvement of the power factor of these two inter-reacting quantities.

18. Actually the generator torque and the motor torque occur as two components of a single combined net motor torque. During parts of the cycle this net torque acts as motor torque and at other parts of the cycle as generator torque. Such a widely variant behavior of the torque causes the speed of the motor to undergo slight cyclical variations. These speed variations are too small to have practical significance, although they are sufficient in magnitude to augment the otherwise noisy operation of the motor.

19. The double-frequency pulsations of the net torque in the motor cause it to develop an inherent noise during operation.[3] The noise occurs as the result of a double-frequency torsional vibration of electromagnetic origin which causes the stator to oscillate about the shaft of the motor as an axis. These torsional vibrations are transmitted in this manner to the base which supports the stator, and thereby, the noise is generated at the base of the motor.

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Electrical Engineering in the Postwar World

III—Engineering: Handmaiden of Economics

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MEMBER AIEE

Third in a series, this article attributes past economic progress to the ways that have been devised by engineering to increase production for a given expenditure of effort. The author predicts that history will repeat itself and that engineering will continue to improve economic well-being as new frontiers are opened. These frontiers are in the realm of the human mind, to which there is no end nor limit, so long as men's imagination and enterprise remain unfettered to explore and extend them.

GOOD ENGINEERING should produce economically sound results, for engineering is but that group of special skills, knowledge, and experience whereby the forces of nature are made useful to mankind. If engineering projects are not economically sound they become a depressing rather than a stimulating influence on the general welfare.

The 30-year period now ending has seen economic miracles performed for the common man in the United States. By and large, the common man works for a living, otherwise he is uncommon. Based on the pay for an hour's work, the industrial worker today gets four times as much as he did 30 years ago. Yet, in the same period, the price of what he buys has gone up only one half, as measured by wholesale prices, and two thirds, as represented by the "cost of living." So he is relatively $3^1/_2$ times better off with respect to wholesale prices and $3^1/_3$ times better off with respect to living costs than he was in 1914. This great gain has been made entirely independent of the gold value of the dollar or any other variables, since the comparable factors before and after have been measured by the same yardstick at the same time. His gain is measured by the comparison between what he got for his work and what he paid for his wants at the same period.

If some industrial or engineering leader had in 1914 predicted that the then coming 30 years would produce for the common man the economic improvement that has in fact occurred, he would have been laughed at as a crazy optimist or criticized as a dangerous boat-rocker.

Since the human being himself was the same before as after, the miraculous improvement in his economic status has necessarily resulted from the more effective use of his time. This more effective use has been made possible by improved machinery, mass production, and mass sales. While a large part of this result has come from improved manufacturing methods, a substantial part of the credit must go to the engineers who have devised the processes and the machines for carrying them out.

Other countries have had their millions of common men, endowed with the same intelligence and potential ability as our own, yet they have made no such economic progress for their average citizen as we have. The magnitude of these differences was strikingly brought out by Gerard Swope, after a trip to Europe six years ago.* He gathered data from eight European countries (designated only by number) and obtained results like the following: The number of hours of work required to purchase a unit of five food items varied from 4.25 to 7.3 among the eight countries. In the United States it was 1.7. To buy an automobile took from 8.5 to 24 months' work in the European countries, compared to 4.5 in our country. In the matter of electricity, to purchase a kilo-watt-hour required from 12 to 43 minutes' work abroad, compared to 3.6 minutes at home. Finally, the acquisition of an incandescent lamp required from 1.2 to 3.4 hours of work from the European workman and only 0.2 hours here. These differences bring out the truly primary cause of the gains we have been able to show—the cause which brought out both the manufacturing and engineering triumphs of the last generation. I refer to the incentive to the exercise of initiative and courage which arises from freedom to make developments and the belief that economically effective pioneering will bring a compensatory reward.

It is essential to keep these fundamentals in mind in planning for the period after the war, because, when that longed-for time arises, we shall find basic things just as they always have been. People will still need their three meals a day, clothing and shelter, transportation and light, and other essential goods and services, and they will want as much more as they can economically get. With human nature and capacity unchanged, the only way by which the common man can rise to higher economic levels must be by his work being made more effective through the tools and methods which management and

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* "Standards of Living," *The Atlantic Monthly*, March 1938.

invention may devise. Neither of these latter has ever flourished in the past except when and where the confidence of reaping adequate reward for special effort and risk was assured by the surrounding institutions. It should be stressed in passing that even the advantages arising from improved management and invention cannot be made completely effective without a marketing system adequate to dispose of the goods produced.

PURE SCIENCE AND APPLIED SCIENCE CONSTITUTE ENGINEERING

It has been the fashion for many years to attempt to draw a contrast between pure science and applied science, frequently, in the business mind, to the derogation of the former. In reality, they are but two parts of the same process of harnessing the forces of nature to the improvement of human life, wherein pure science furnishes the raw materials of fact and applied science the finished product made from those raw materials. One is just as essential as the other; engineering comprises both.

The history of electrical engineering is replete with the mutual dependence of these two factors. The great electric power industry of today rests squarely upon the raw-material fact, discovered by Faraday in 1831, that a closed conducting loop forced through a magnetic field produces an electric current in the circuit. Without this fact, the great present development could not exist; without the development, the fact would be but a laboratory stunt. It was discovered very early that an electric current passing through a conductor could heat it hot enough to emit light—a fact which became of transcendent importance when Edison, with a carbon filament operating in a vacuum, produced a light source that would not quickly burn itself out.

There is a close analogy in principle between the improvement in fuel economy of steam-driven prime movers and the gain in efficiency of electric-light sources since the early days. In each case, the early models wasted most of the energy put into them. In the case of the prime mover, the utilizable heat range (from the simple noncondensing engine to the modern turbine) has been magnified ten-fold; in the case of the light source (from the original carbon lamp to the modern fluorescent lamp) the usable light from a given energy input has likewise been increased ten-fold by eliminating the useless, because invisible, heat waves. Each step in this upward movement resulted from the application of the raw materials of discovered fact to practical application. Incidentally, household electric rates in the carbon-filament days were six times what they are today, although hourly labor costs are now four times as great.

The extraordinary gains in the economy of light sources have been the result of numberless engineering studies of details that would seem to the layman of minor importance. Lowering the absorption losses in glass from some 30 per cent to 10 per cent is one of these; another is the discovery that whether the crystals lie along or across the fine tungsten-wire filament means the difference between a relatively shock-resistant lamp or one that breaks easily.

Historically, the discovery of the electric arc considerably antedates the incandescent lamp. One of the earliest observations regarding this phenomenon was its very high temperature. This factual raw material is the basis for the modern electric furnaces, which in 1943 turned out nearly 8,000,000 tons of steel and ferroalloys. The great increase of electric steel capacity (six-fold in four years) has been due to the marked homogeneity of the product from electric furnaces and to the accuracy with which its composition can be controlled electrically. The consumption of electric energy in 1943, arising from this particular bit of factual raw material (8.3 billion kilowatt-hours) was about the same as was consumed 15 years ago by all the 19,000,000 homes in the United States which were then using electricity.

HISTORY CONTINUES TO REPEAT ITSELF

Attempting to look into the future on the basis of things just emerging, we see history repeating itself in the translation of laboratory knowledge into economic improvement. In some respects, electricity would seem to be the least economical source of heat for industrial processes. Yet it is precisely in the matter of heat that some of the most striking recent advances in industrial use have been developed. The really amazing economic results that have been achieved have arisen from the speed and concentrated application which electricity alone has made possible. High-frequency electric heat acts so quickly that tin can be successfully flowed on a sheet moving 1,000 feet a minute, and with dielectric high-frequency heating the time of setting glue in laminated structures has been reduced from six hours to 15 minutes.

It may prove to be good engineering to heat the human body for comfort rather than to expend fuel and capital in the heretofore common but inefficient means of air heating indoors. The same thing applies to cooking. We may justify projecting heat directly to the food rather than, as now, wastefully heating the whole kitchen. Perhaps it may turn out that our current methods of indoor heating are similar in economy to the process of "burning down the barn to get a mess of roast pork."

Engineering applied to translating electric energy into radiant energy with a wave length of 2,537 angstroms may mean fewer disease germs, sterile wounds, and lessened losses on foods from mold—all influences to lengthen human life. Engineering study of electric fields has led to the electric air filter. The economic value of dust-free air in saving maintenance cost and the endless drudgery of dusting and washing is at once apparent.

In all the illustrations I have cited, the ingenuity and imagination of the engineer have used the raw material of previously observed phenomena to produce practical results of definite economic worth.

STANDARDIZATION OFFERS ECONOMIES TO ELECTRIC UTILITIES

The electric-utility business is characterized by an especially high investment per dollar of annual gross revenue—about seven times as much as the average manufacturing industry. From this it follows that one of the most important problems facing that industry is that of keeping down or reducing the unit cost of utility-plant investment. The cost of the larger items of electric generating and translating equipment is greatly affected by the high overhead cost of special designs. Experience during the war has demonstrated that drastic cuts in cost could be effected as a result of the need for larger quantities of pieces of apparatus of which relatively few were needed in peacetime. In fact, it was the drastic effect of the repetitive process on costs, compared to those based on previous manufacturing experience, that first called, from the manufacturers themselves, for renegotiation of war contracts.

For the future, a corresponding result can be obtained by the maximum amount of standardization of the major items of generating and transforming equipment. This has already been recommended by some of the larger manufacturers and is the subject of studies by committees of the engineering societies concerned. It is a consistent sequel to the recent war experience and to the nature of our past industrial development. The practical application of standardization calls for a statesmanlike co-operation between the designing engineers of the utilities and the production engineers of the manufacturers. The process is already under way; it should be progressively developed.

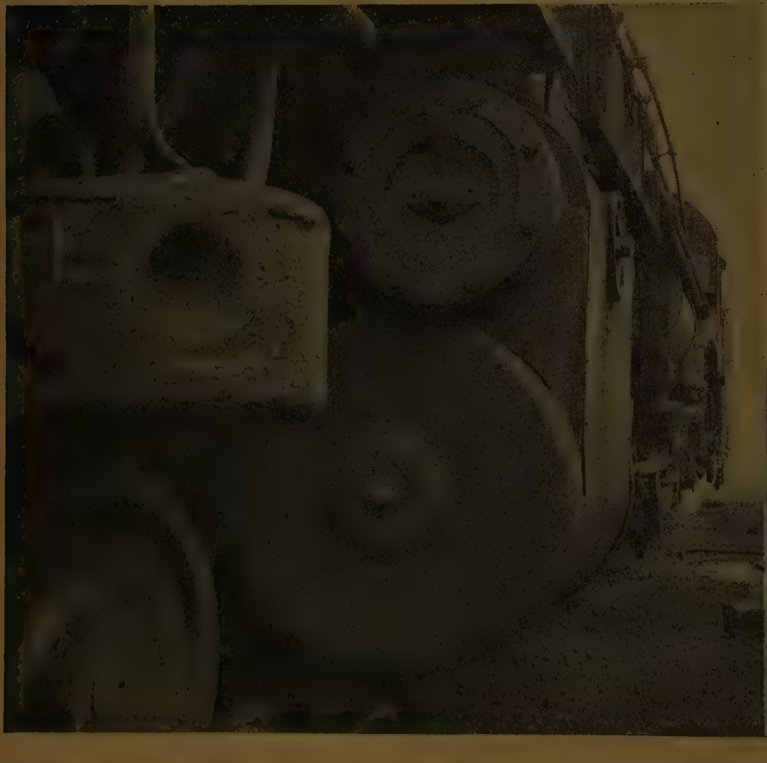
In recent years, perhaps the most conspicuous examples of engineering economics are the electrical interconnection of plants and systems, and topping turbines. The former effected economies in investment by making unnecessary many individual plant reserves formerly required, and in operating cost by maximum utilization of the most efficient plants. The latter has not only improved economy by enlarging the usable heat range, but has also lengthened the life of already existing units by bringing them usefully into the higher heat cascade.

NEW FRONTIERS—IN THE HUMAN MIND

Returning, in closing, to the thesis from which we started, our past economic progress has been largely due to the ways engineering has devised to enable the relatively changeless human faculties to get more effective results from a given human effort. After the war, progress must depend upon more development along those same lines. Much oratory and printers' ink have been expended lamenting the loss of the "frontier"—the physical frontier, whose extension, however, meant simply a wider area in which to exercise the same old human abilities as existed before the extension. The frontiers that have opened up in the last generation (after the *physical* frontiers had been pushed aside) have proved to offer much greater opportunities for improved economic well-being than the mere clearing of forests and settlement of land which were involved in the extension and final crossing of the last physical frontier.

These new frontiers are in the realm of the human mind, to which there is no end or limit, so long as man's imagination and enterprise remain unfettered to explore and extend them. In the field of electrical engineering this frontier country is particularly broad, rich, and inviting. May we, as a nation, have the good sense to realize that the effective area of our expansion territory, being of the mind and spirit, will depend predominantly upon the ability of mind and spirit to go forward in its exploration with perfect freedom!

Pennsylvania Trains Adopt Telephones



A two-way electronic train telephone system produced in co-operation with the Union Switch and Signal Company has been installed on the 67-mile Belvidere-Delaware branch of the Pennsylvania Railroad. The projecting bar behind the wheel of the freight locomotive (left) is the system receiving coil, and the equipment box is above the driving wheels. The headlight generator supplies electric power. In the cab are the telephone handset and the loudspeaker which reproduces signals from the block operators in wayside towers and the crew and conductor in the rear of the train. Communication with other trains in the system also is possible

INSTITUTE ACTIVITIES

Pacific Coast Technical Meeting Will Reflect Aircraft Interest

Arrangements are being made for an enlarged technical program for the Pacific Coast technical meeting, which will be held in Los Angeles, Calif., August 29–September 1. Meeting headquarters will be in the Biltmore Hotel.

Present indications point toward a program of approximately 20 technical sessions and conferences, at which some 50 technical papers will be presented during the four days of the meeting. Most of the sessions and papers will deal with electric equipment for military planes, because of the extent and importance of the aircraft industry on the Pacific Coast. Practically every phase of electrical applications to aircraft will be considered and there will be sessions on generators, motors, instruments, protective devices, radio-insulation problems, ignition, lighting, and maintenance. However, the program will not be devoted entirely to aircraft, as there will be a few papers in the central-stations field, which will discuss power generation, transmission, system stability, relays, and circuit breakers.

The personnel of the 1944 Pacific Coast technical meeting committee and chairmen of subcommittees is as follows:

T. M. Blakeslee, *general chairman;* E. S. Condon, *secretary-treasurer;* C. E. Baugh, M. M. Bridgwater, H. L. Caldwell, C. R. Davis, Fred Garrison, J. M. Gaylord, Thomas Ingledow, W. T. Johnson, A. O. Mangold, H. E. Mellrud, T. A. Robinson, E. W. Schilling, H. V. Strandberg; P. L. Johnson, *technical program;* G. R. Woodman, *registration;* R. F. Gheen, *hotel;* Bradley Cozzens, *arrangement;* Fred Foulon, aircraft activities; E. W. Morris, electronics activities; F. W. Maxstadt, *students activities;* A. D. Brown, *finance;* J. H. Vivian, *publicity;* P. L. Savage, *inspection trips;* and R. A. Hopkins, *educational.*

AIEE Board of Directors Meeting

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, N. Y., May 25, 1944.

The board authorized the regular allowance for traveling expenses for a joint conference on student activities of Districts 8 and 9 and the University of British Columbia Branch, during the 1944 Pacific Coast technical meeting of the Institute in Los Angeles, Calif.

An appropriation of $9,430 was made for the presentation and publication of additional technical papers during the remainder of the present appropriation year, ending September 30, 1944. The additional funds were set aside at the recommendation of the technical program committee, which reported an increase in the number of papers over that estimated when the budget for the year was adopted, brought about principally by the large number of air transportation papers offered, as well as papers in the electrochemistry, electrometallurgy, welding, and industrial applications and control fields. All papers scheduled for regular sessions to date are considered by the respective technical committees to be important, and their presentation consistent with the board's wartime policy.

The national treasurer reported on the financial condition of the Institute for the fiscal year ending April 30, 1944, and the annual report of the board of directors, prepared under the direction of the national secretary, was approved for presentation at the annual meeting of the Institute, in St. Louis, June 26, 1944.

In accordance with section 37 of the constitution, the appointment of a national secretary for the administrative year beginning August 1, 1944, was considered. National Secretary H. H. Henline was reappointed.

Upon recommendation of the committee on planning and co-ordination, it was voted to hold the 1945 winter technical meeting of the Institute in New York, N. Y., January 22–26.

Upon recommendation of the vice-president of the Canada District (10), the Montreal Section, and the Sections committee, the maritime provinces of New Brunswick, Nova Scotia, and Prince Edward Island were added to the territory of the Montreal Section.

Upon recommendation of the standards committee, a revision of Part III—"Protection of Structures Containing Flammable Liquids and Gases" of the Code for Protection Against Lightning, was approved for submission to the American Standards Association as a revised American Standard. This was developed by sectional committee *C*5, Code for Protection Against Lightning, for which the AIEE and the National Bureau of Standards are joint sponsors. Participation with other organizations in the work of standardization of aeronautical electric equipment was authorized. Co-operation in a revision of the "Handbook of Interior Wiring Design" by the appointment of two representatives on the Industry Committee on Interior Wiring Design, was authorized. Appointment of Thomas Spooner as an additional AIEE representative on sectional committee *Z*32 "Graphical Symbols and Abbreviations for Use on Drawings" was approved.

The board approved the appointment by the president of the following committee of tellers to canvass and report on the ballots cast for the 1944 election of officers of the Institute:

R. C. Darrow (*chairman*), J. E. Burroughs, Franklin J. Johnson, Howard W. Meehan, E. K. Murphy, George T. Royden, and Charles H. Wagner.

The nomination of an AIEE representative for election by the board of trustees of the United Engineering Trustees, Inc., to The Engineering Foundation board for the four-year term beginning in October 1944, was referred to the president with power.

L. R. Mapes was reappointed an Institute representative on the Washington Award Commission for the two-year term beginning June 1, 1944.

Upon recommendation of the special committee on registration of engineers, the board voted not to approve the "Model Law for the Registration of Professional Engineers and Land Surveyors and Providing for the Certification of Engineers-in-Training," dated June 1943 and submitted by the American Society of Civil Engineers with a request for approval and endorsement.

As a result of a suggestion looking toward a continuing record of historical happenings in the fields of Institute activity, that is, carrying on the history of the first fifty years of the Institute contained in the Golden Anniversary issue of *Electrical Engineering* (May 1934), it was voted to request the technical program committee to review the past ten years and prepare a history of the high spots for publication in some future issue of *Electrical Engineering.*

Approval was given to a program, submitted by the Engineers' Council for Professional Development, for the accrediting, under the direction of the ECPD committee on engineering schools, of the curricula (non-degree) of technical institutes.

In response to a suggestion of the American Welding Society, the president was authorized to appoint a representative of the Institute on a proposed committee of representatives of various organizations to study the question of establishing agencies for the qualification of welding operators, for which there is a growing demand on the part of industry and public authorities.

The board appropriated $200 for the purpose of acquiring and distributing to electrical engineering students pamphlet copies of "The Second Mile—A Resurvey," by William E. Wickenden, in a manner to be determined by the committee on Student Branches.

Other matters were discussed, reference to which may be found in this or future issues of *Electrical Engineering.*

Other actions taken included the following:

Minutes were approved of the meeting of the board of directors held January 27, 1944, and the meeting of the executive committee April 26, 1944.

Recommendations adopted by the board of examiners at its meeting on May 18, 1944, were approved. The following actions were taken upon recommendation of the board of examiners: eight applicants were transferred to the grade of Fellow; 38 applicants were transferred, and 69 were elected to the grade of Member; 437 applicants were elected to the grade of Associate; one Member and one Associate were reinstated; and 319 Students were enrolled.

Disbursements were reported by the finance committee and approved by the board, as follows: February, $29,311.52; March, $25,216.34; April, $29,957.93; May, $30,739.02.

Those present were:

President—Nevin E. Funk, Philadelphia, Pa. *Past President*—David C. Prince, Schenectady, N. Y. *Vice-Presidents*—W. J. Gilson, Toronto, Ont., Canada; C. R. Jones, New York, N. Y.; K. B. McEachron, Pittsfield, Mass.; C. W. Ricker, New Orleans, La. *Directors*—T. F. Barton, New York, N. Y.; M. S. Coover, Ames, Iowa; K. L. Hansen, Milwaukee, Wis.; T. G. LeClair, Chicago, Ill.; S. H. Mortensen, Milwaukee, Wis.; W. B. Morton, Philadelphia, Pa.; W. R. Smith, Newark, N. J.; R. G. Warner, New Haven, Conn. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y.

Contents of June 1944 Supplement Announced

The nine remaining technical papers presented at the 1944 AIEE winter technical meeting and not published in the monthly

Transactions sections of *Electrical Engineering* will appear in the June 1944 "Supplement to Electrical Engineering—Transactions Section" to be released shortly. The discussions of these papers and the discussions of the technical papers published in the January–June monthly sections also will be included in the supplement. This will complete the publication of papers and discussions presented at the New York winter meeting.

Copies of the supplement will be mailed shortly to those who entered advance orders. Others may obtain copies at 50 cents each from the AIEE order department, 33 West 39th Street, New York 18, N. Y., as long as the limited supply lasts.

The following papers which have been abstracted in *Electrical Engineering* will be printed in the supplement:

44-57—Effect of Altitude on Electric Breakdown and Flashover of Aircraft Insulation; *L. J. Berberich* (*M '36*), *G. L. Moses* (*A '43*), *A. M. Stiles* (*A '43*), *C. G. Veinott* (*M '34*). Abstracted in the January 1944 issue, page 26.

44-10—Transformer Magnetizing Inrush Currents and Influence on System Operation; *L. F. Blume* (*F '39*), *G. Camilli* (*F '43*), *S. B. Farnham* (*M '42*), *H. A. Peterson* (*M '41*). Abstracted in the December 1943 issue, page 546.

44-44—The Geometry of Arc Interruption—II. Current-Zero Phenomena; *E. W. Boehne* (*F '43*). Abstracted in the January 1944 issue, page 30.

44-62—Cost Study of 69- to 345-Kv Overhead Power-Transmission Systems; *J. G. Holm* (*M '29*). Abstracted in the January 1944 issue, page 30.

44-40—The Capacitor—an Aid to Electric-Power Service for Pipe Lines; *M. A. Hyde* (*A '27*), *R. E. Marbury* (*M '36*). Abstracted in the January 1944 issue, page 28.

44-53—Current Rating of Cables as Affected by Mutual Heating in Air or Conduit; *committee on research, Insulated Power Cable Engineers Association.* Abstracted in the January 1944 issue, page 29.

44-38—Electric-Circuit Fault-Protective Principles as Applied to D-C Aircraft Systems; *R. H. Kaufman* (*M '41*). Abstracted in the January 1944 issue, page 27.

44-17—Lightning Protection for Rotating Machines; *G. D. McCann* (*M '44*), *E. Beck* (*M '35*), *L. A. Finzi* (*A '40*). Abstracted in the December 1943 issue, page 547.

44-61—Electric Equipment for the War Emergency Pipe-Line Projects; *E. E. Thomas* (*M '29*), *W. G. Taylor*, *Oscar Wolfe*. Abstracted in the January 1944 issue, page 28.

Officers for 1944–45 Announced at St. Louis Meeting

Institute officers for the year beginning August 1, 1944, were announced in the report made by the committee of tellers to the annual meeting of the AIEE held June 26, during the summer technical meeting in St. Louis, Mo. The new officers are:

President: Charles A. Powel, manager, headquarters engineering departments, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Vice-Presidents: R. T. Henry, assistant chief electrical engineer, Buffalo (N. Y.), Niagara and Eastern Power Corporation (District 1, North Eastern); J. F. Fairman, assistant vice-president, Consolidated Edison Company of New York (N. Y.) Inc. (District 3, New York City); M. S. Coover, professor and head of the department of electrical engineering, University of Iowa, Ames (District 5, Great Lakes); R. W. Warner, professor and head of the department of electrical engineering, University of Texas, Austin (District 7, South West); C. B. Carpenter, assistant chief engineer, general engineering department, Pacific Telephone and Telegraph Company, Portland, Ore. (District 9, North West).

Directors: P. L. Alger, assistant to the vice-president in charge of engineering, General Electric Company, Schenectady, N. Y.; M. J. McHenry, director of sales promotion, Hydro-Electric Power Commission, Toronto, Ont.; D. A. Quarles, director of transmission development, Bell Telephone Laboratories, Inc., New York, N. Y.

Treasurer: W. I. Slichter, professor emeritus of electrical engineering, Columbia University, New York, N. Y.

The board of directors for the administrative year beginning August 1, 1944, will consist of the foregoing elected officers and the following holdover officers:

Nevin E. Funk, Philadelphia, Pa. (*retiring president*); H. S. Osborne, New York, N. Y. (junior past president); L. A. Bingham, Boulder, Colo.; J. M. Gaylord, Los Angeles, Calif.; W. J. Gilson, Toronto, Ont.; C. W. Ricker, New Orleans, La.; W. E. Wickenden, Cleveland, Ohio (*vice-presidents*); L. R. Gamble, Spokane, Wash.; K. L. Hansen, Milwaukee, Wis.; C. M. Laffoon, East Pittsburgh, Pa.; T. G. LeClair, Chicago, Ill.; F. R. Maxwell, Jr., Pensacola, Fla.; C. W. Mier, Dallas, Tex.; S. H. Mortensen, Milwaukee, Wis.; W. B. Morton, Philadelphia, Pa.; W. R. Smith, Newark, N. J. (*directors*).

A detailed report of the summer technical meeting at St. Louis, Mo., is scheduled for the August issue.

National and District Prizes Awarded at Summer Meeting

Announcement of the 1943 recipients of the national prizes for the best papers in four fields was made by F. A. Cowan, chairman of the AIEE committee on award of Institute prizes and presentation of the prizes was made by AIEE President Nevin E. Funk on June 26 at the annual meeting of the Institute in St. Louis, Mo. As in 1940, 1941, and 1942 no award was made for 1943 in the field of public relations and education because no eligible papers were presented.

The selections of the committee were:

Best Paper in Engineering Practice: Prize awarded to L. R. Ludwig (M '41) and W. M. Leeds (M '38) of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., for their paper, "A Multiorifice Interrupter for High-Voltage Oil Circuit Breakers," presented at the 1943 national technical meeting, January 25–29, and published in the 1943 *Transactions*, pages 119–25. Honorable mention was awarded to L. O. Grondahl (M '42) and P. N. Bossart of the Union Switch and Signal Company, Swissvale, Pa., for their paper, "Train Communication," presented at the 1943 North Eastern District meeting, April 8–9, and at the 1943 South West District meeting, April 26–30, and published in the 1943 *Transactions*, pages 493–500.

Best Paper in Theory and Research: Prize awarded to B. R. Teare, Jr. (F '42) and Mrs. J. R. Webb (A '41) of the Carnegie Institute of Technology, Pittsburgh, Pa., for their paper, "Skin Effect in Bimetallic Conductors," presented at the 1943 national technical meeting, January 25–29, and published in the 1943 *Transactions*, pages 297–302. Honorable mention was awarded to R. V. Shepherd (M '43) and C. E. Kilbourne (M '37) of the General Electric Company, Schenectady, N. Y., for their paper, "The Quadrature Synchronous Reactance of Salient-Pole Synchronous Machines," presented at the 1943 national technical meeting, June 21–25, and published in the 1943 *Transactions*, pages 684–89.

Initial Paper: Prize awarded to Fred Foulon (F '42) of the Douglas Aircraft Company, El Segundo, Calif., for his paper, "Radio-Noise Elimination in All-Metal Aircraft," presented at the 1943 national technical meeting, September 2–4, and published in the 1943 *Transactions*, pages 877–91. Honorable mention was awarded to H. H. Fahnoe (A '35) of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., for his paper, "A New High-Interrupting-Capacity Fuse for Voltages Through 138 Kv," presented at the 1943 national technical meeting, June 21–25, and published in the 1943 *Transactions*, pages 630–35.

Branch Paper: Prize awarded to R. W. Cronshey (Enrolled Student) of the Michigan College of Mining and Technology, Houghton, for his paper, "A Simple Graphical Method for Calculating Antenna Radiation Patterns," presented at a meeting of the college Student Branch, January 27, 1943.

DISTRICT PRIZES

District prizes for AIEE papers have been announced by seven Districts. The awards are for papers presented during 1943, except Branch papers, which were presented during the academic year ending June 30, 1943.

District 1

Prize for best paper was awarded to S. Minneci (A '38) and S. B. Farnham (M '42) for their paper "A New Control System for Automatic Parallel Operation of Load-Ratio-Control Transformers," presented at the North Eastern District technical meeting, Pittsfield, Mass., April 8–9, 1943.

District 2

Prize for best paper was awarded to B. R. Teare, Jr. (F '42) and Josephine R. Webb (A '41) for their paper "Skin Effect in Bimetallic Conductors," presented at a meeting of the Pittsburgh Section, February 14, 1943.

Prize for initial paper was awarded to H. C. Marcroft (A '31) for his paper "Use of Dielectric Absorption Tests in Drying Out Large Generators," presented at a meeting of the Maryland Section, April 5, 1943.

District 5

Prize for Branch paper was awarded to R. W. Cronshey (Enrolled Student) for his paper "A Graphical Method for Calculating Antenna-Radiation Patterns," presented at a meeting of the Michigan College of Mining and Technology Branch, January 27, 1943.

District 6

Prize for best paper was awarded to L. M. Robertson (M '38) for his paper "Electric Performance and Investigations at High Altitudes," presented at a meeting of the Denver Section, October 15, 1943.

Prize for Branch paper was awarded to R. J. Carlson (Enrolled Student), G. L. Harvey (Enrolled Student), and W. H. Clark, for their paper "A Two-Speed A-C Generator," presented at a meeting of the University of Denver Branch, April 27, 1943. Honorable mention for this prize was given to C. A. Stutt, for his paper "Experiences With a D-C Calculating Board," presented at a meeting of the University of Nebraska Branch, April 14, 1943.

District 7

Prize for Branch paper was awarded to J. N. Leedom (A '44) for his paper "Ultrahigh-Frequency Transmission in Hollow Guides," presented at a meeting of the Rice Institute Branch, March 1, 1943.

District 8

Prize for best paper was awarded to Fred Foulon (N '42) for his paper "Radio-Noise Elimination in All-Metal Aircraft," presented at the National technical meeting, Salt Lake City, Utah, September 2–4, 1943.

District 10

Prize for best paper was awarded to A. E. Davison (A '13) for his paper "Meteorological Services for Designers and Operators of Electric-Power Systems," presented at a meeting of the Toronto Section, October 25, 1943.

Prize for initial paper was awarded to C. A. Laverty (A '33) for his paper "Causes and Effects of Damage to Electrical Machinery and Switching Equipment," presented at a meeting of the Toronto Section, November 12, 1943.

Additions to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and paid dues for 30 years. A list of those who have become members for life during the preceding year is published annually in *Electrical Engineering*. Institute members who have attained this status since publication of the last list in the July 1943 issue are:

L. F. Adams
D. J. Angus
R. W. Atkinson
A. Ball
S. Barfoed
C. J. Barrow
H. C. Bartholomew
F. G. Beetem
H. C. Blackwell
O. B. Blackwell
L. F. Blume
L. N. Boisen

F. C. Bolton
W. T. Booth
H. V. Bozell
O. C. Brill
S. N. Castle
L. W. Chubb
F. W. Cloud
W. D. Coolidge
M. Cornelius
I. L. Craig
E. J. Crawford
W. A. Darrah
E. G. Davis
H. P. Dodge
C. E. Drennen
A. M. Dudley
A. J. Duncan, Jr.
H. E. Dunham
H. E. Dyche
E. J. Edwards
H. E. Eisenmenger
L. S. Ford
E. H. Freeman
W. W. Gaskill
I. H. Gaskin
A. S. Glasgow
C. Goldsmith
V. Greiff
F. G. Hamilton
J. D. Harnden
F. E. Haskell
J. W. Herman
W. G. Hewson
H. H. Higbie
V. L. Hollister
B. D. Horton
P. J. Howe
A. H. Hull
D. J. Hutton
J. G. Jackson
A. N. Johns
C. A. Johnson
C. E. Johnson
J. C. Jones
J. E. Kearns
C. H. Keel
W. G. Kelley
J. N. Kelman
E. H. Kifer
J. Klemm
O. A. Knopp
C. le Maistre
H. Lippelt
E. A. Loew
M. H. Logan
H. C. Louis
B. S. Luther
R. B. MacGuinness
G. K. Manson
A. C. Marshall
J. C. Marshall
C. L. Matthews
G. W. McIver, Jr.
W. J. McKeen
F. W. Merrill
J. L. Merrill
L. T. Merwin
J. W. Morrison
J. Morse
S. H. Mortensen
H. Mouradian
J. A. Moyer
A. Mullhaupt, Jr.
E. J. Nathan
E. E. Nelson
F. Oppenheimer
D. P. Orcutt
O. W. Paddock
R. G. Parrott
B. H. Peck
H. B. Peirce
C. S. Peters
E. W. Pragst
C. L. Proctor
R. J. Randolph
C. R. Reid
S. Ring
E. B. Rollins
G. W. Saathoff
D. R. Shearer
O. F. Shepard, Jr.
W. M. Shepard
J. W. Shuman
T. Smith
E. S. Steinbach
W. Sykes
W. S. Taussig
H. Thomas
A. I. Totten
M. Unger
H. R. Van Deventer
R. S. Wallace
G. A. Waters
G. G. Watson
L. R. Waugh
E. Weber
F. D. Weber
D. S. Wegg
A. C. Wood
E. M. Wood
C. D. Woodward
E. B. Woodward
C. E. Young
F. Zogbaum

These members of the Philadelphia Section received special prizes for faithful attendance at meetings throughout the year. Shown with their prizes, they are left to right, standing: J. D. Wood (M '27), A. E. Pringle (A '36), and H. S. Phelps (A '21); second row: L. R. Baker (A '43), and Frank McDonald (A '38); and foreground: N. R. Cox (M '43), L. Haines (A '17), and A. C. Finney (A '07)

SECTION • • • • •

Philadelphia Section Elects Executive Officers for 1944–45

The Philadelphia Section of the AIEE, meeting at the Engineers Club on May 8, 1944, for the last session of the season, approved a revision in the bylaws to permit the organization of Subsections. Also accomplished during the business of the meeting was the election of executive officers for the 1944–45 season. They are:

Chairman, A. C. Muir (M '39) electrical engineer, Berwind-White Coal Mining Company.

Vice-chairman, C. T. Pearce (M '40) Middle Atlantic engineering and service manager, Westinghouse Electric and Manufacturing Company.

Secretary, M. L. Lehman (M '36) project engineer, Philadelphia Electric Company.

The prize-papers committee, under the chairmanship of L. E. Howard (A '40), awarded cash prizes to C. S. Schifreen (M '43), O. B. Vikoren (M '43), and H. C. Warner, for the best papers entered in the Section prize-paper competition. Two of the winning papers were presented to the meeting.

Mr. Schifreen, discussing "Fatigue of Lead Sheath on Underground Cable," reported that failure records of large mileages of cable indicate that ratings are limited much more by the physical proportionments than by inherent weaknesses in insulation or sheath. To support this claim he presented the results of accelerated tests in a unique full-scale dummy manhole and duct run, which indicated the relationships of loading, conductor temperature changes, and movement in manholes and ducts to sheath life. The paper suggested a method of computing life expectancy for different loadings as a function of manhole dimensions.

"Transformer Arrangements for Large Motor Loads," by H. C. Warner, considered the problems encountered in the design of a large pumping station, particularly with respect to the best voltage ratings of the motors and co-ordinated switching and starting equipment. It presented a method for solving such problems, and for obtaining a simple reliable system that will utilize standard equipment with high efficiency, low capital investments, and low maintenance costs. Both papers were accompanied by slides illustrating the features outlined.

As a grand finale a large number of special prizes were distributed for faithful attendance at Section meetings throughout the season.

STANDARDS • • •

AIEE to Participate in Aeronautical Standardization

Remarkable strides have been made in the development of electric equipment for aeronautical purposes. The Institute, with its broad background of knowledge and experience in the preparation of electrical Standards, plans to participate to the fullest extent possible in the preparation of aeronautical electric-equipment Standards. To date, much of the standardization work on aeronautical equipment has been carried on under the auspices of Society of Automotive Engineers and the National Aircraft Standards Committee.

At the AIEE Standards committee meeting, May 23, 1944, it was decided that the assistance of the Institute in this work should be offered to the NASC and the SAE. This has been done, and these organizations desire to take full advantage of the possibilities. It is believed that the Institute can be particularly helpful in formulating fundamental electrical Standards including performance characteristics of aeronautical electric equipment and devices, test codes, and methods of demonstrating specified performance, and methods of calculation.

New Standard. American Standard *C* 62.1, "Lightning Arresters for A-C Power Circuits," which is a revision of the AIEE and American Standard 28, has been approved. It applies to all types of lightning arresters designed for a-c circuits having an element with nonlinear volt-ampere characteristic to limit the current. The Standard is 30 cents per copy with 50 per cent discount to AIEE members on single copies.

Future AIEE Meetings

Pacific Coast Technical Meeting
Los Angeles, Calif., Aug. 29–Sept. 1, 1944

PERSONAL ● ● ● ●

L. R. Ludwig (A '28, M '41) manager of the motor division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been awarded the 1943 best paper prize in engineering practice as coauthor of the paper, "A Multiorifice Interrupter for High-Voltage Oil Circuit Breakers." Mr. Ludwig was graduated from the University of Illinois in 1925 with the degree of bachelor of science in electrical engineering. Employed by the Westinghouse company as a graduate student in 1925, he worked as assistant to the chief electrical engineer from 1926 to 1928 and in the latter year was transferred to the railway motor engineering department. He became section engineer in the research laboratory in 1930, manager of circuit-breaker and protective-devices engineering in 1935, and manager of the motor division in 1944. As the recipient of the first Benjamin Lamme scholarship he studied at the University of Berlin in 1929–30. He was coauthor of the paper receiving the national best paper prize in the field of theory and research in 1934 and received honorable mention for his paper in that field in 1935.

W. M. Leeds (A '32, M '38) electrical engineer, switchgear engineering department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been awarded the 1943 national best paper prize in engineering practice as coauthor of the paper "A Multiorifice Interrupter for High-Voltage Oil Circuit Breakers." He received the degree of bachelor of science from Haverford College in 1926 and that of master of science from the University of Pittsburgh in 1930. Mr. Leeds has been associated with the Westinghouse Company since 1927 first as engineer in the circuit breaker engineering division and since 1939 in the switchgear engineering department. In 1937 he was awarded the Benjamin Lamme scholarship for graduate study and spent one year at Massachusetts Institute of Technology, Cambridge. He is a member of Phi Beta Kappa and Sigma Xi.

B. R. Teare, Jr. (A '29, F '42) professor of electrical engineering, Carnegie Institute of Technology, Pittsburgh, Pa., has been awarded the 1943 national best paper prize in theory and research as coauthor of the paper, "Skin Effect in Bimetallic Conductors." This paper also was awarded the 1943 best paper prize by District 2. He received from the University of Wisconsin the degrees of bachelor of science in 1927 and master of science in 1928 and from Yale University the degree of doctor of engineering in 1937. He entered the employ of the General Electric Company, Schenectady, N. Y., in 1928 and until 1933 worked in the testing department, the research laboratory, and the general engineering department. Joining the faculty of Yale University, New Haven, Conn., as instructor in electrical engineering in 1933 he was named assistant professor in 1934. Since 1939 Doctor Teare has been associated with the Carnegie Institute of Technology as professor of electrical engineering. He is a member of the Society for the Promotion of Engineering Education and of the Institute of Radio Engineers.

L. R. Ludwig

Fred Foulon

W. M. Leeds

Josephine R. Webb (A '41) development engineer, power circuit breaker department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been awarded the 1943 national best paper prize in theory and research as coauthor of the paper, "Skin Effect in Bimetallic Conductors." This paper also was awarded the District 2 prize for best paper for 1943. Mrs. Webb received the degree of bachelor of science in electrical engineering from Purdue University in 1940. In 1940 she was employed as technical assistant at Carnegie Institute of Technology, Pittsburgh, Pa., and in 1942 entered the employ of the Westinghouse Company for which she worked first in the ignitron research laboratory.

Fred Foulon (A '30, M '42) electrical engineer, engineering department, El Segundo (Calif.) plant, Douglas Aircraft Company, has been awarded the 1943 national prize award for best initial paper for his paper, "Radio-Noise Elimination in All-Metal Aircraft." This paper also was awarded the District 8 prize for best paper of 1943. Mr. Foulon received the degree of bachelor of science in engineering from the University of California in 1928 and the degree of master of science in electrical engineering from the California Institute of Technology in 1932. After a short time in the test department of the San Diego (Calif.) Consolidated Gas and Electric Company, he joined the Electrical Research Products Company, Seattle, Wash., as supervising engineer in 1929. He was engineer in the sound department of Warner Brothers Pictures, Hollywood, Calif., from 1933 to 1937 and in the sound department of Universal Pictures, Hollywood, in 1937. He joined the Douglas Aircraft Company in 1938 as research analyst.

R. W. Cronshey (Enrolled Student) lieutenant in the United States Army Signal Corps, has been awarded the 1943 national prize award for Branch paper for his paper, "A Simple Graphical Method for Calculating Antenna Radiation Patterns." This paper also was awarded the District 5 prize for best Branch paper for 1943. Lieutenant Cronshey was born in Newark, N. J., May 14, 1918. Before entering Michigan College of Mining and Technology in 1938, he worked in the laboratory of the Western Electric Company, Kearny, N. J. While attending college, from which he graduated with the degree of bachelor of science in electrical engineering in 1943, he was chief operator for radio station W9YX and also instructed a class in amateur radio. In 1943 he was commissioned a second lieutenant in the Signal Corps. For a time he was stationed at Fort Monmouth, N. J., and is currently serving overseas. He is a member of Eta Kappa Nu and Tau Beta Pi.

L. O. Grondahl (A '26, M '42) director of research and engineering, Union Switch and Signal Company, Swissvale, Pa., has received honorable mention in the 1943 national prize award for the best paper in engineering practice as coauthor of the paper, "Train Communication". Doctor Grondahl holds the degrees of bachelor of science (1904) from St. Olaf College and of master of science (1905) and doctor of philosophy (1908) from Johns Hopkins University. In 1940 he was awarded the honorary degree of doctor of science by the latter. He served as lecture assistant at Johns Hopkins University, Baltimore, Md., in 1906 and instructor in physics at Spokane (Wash.) College in 1908, and at the University of Washington, Seattle, in 1909. He joined the Carnegie Institute of Technology as instructor in 1912, becoming assistant professor in 1914, and associate professor in 1917. Since 1920 he has been director of research for the Union Switch Company and in 1937 was named director of research and engineering. He holds numerous patents.

R. V. Shepherd (A '36, M '43) electrical engineer, motor and generator engineering department, General Electric Company, Schenectady, N. Y., has received honorable mention in the national prize award for the best paper in the field of theory and research as coauthor of the paper, "The Quadrature Synchronous Reactance of Salient-Pole Synchronous Machines." A 1935 graduate of the University of Illinois Mr. Shepherd immediately entered the test department of the General Electric Company and in 1937 was transferred to the motor and generator engineering department.

C. E. Kilbourne (A '29, M '37) designing engineer, motor and generator engineering department, General Electric Company, Schenectady, N. Y., has received honorable

R. W. Cronshey

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B. R. Teare, Jr.

mention in the national prize award for the best paper in the field of theory and research as coauthor of the paper, "The Quadrature Synchronous Reactance of Salient-Pole Synchronous Machines." Mr. Kilbourne received his bachelor of science degree from Virginia Military Institute in 1927 and his professional engineering degree from that institution in 1931. He entered the test department of the General Electric Company in 1927 and the a-c engineering department which later became the motor and generator engineering department in 1929

H. H. Fahnoe (A '35) design engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has received honorable mention in the national prize award for best initial paper for his paper, "A New High-Interrupting-Capacity Fuse for Voltages Through 138 Kv." A 1934 graduate of Cornell University, Mr. Fahnoe joined the Westinghouse Company as a graduate student in 1935 and was named design engineer in 1936.

J. P. McKearin (A '11, F '38) chief engineer, Western Massachusetts Companies, Springfield, has retired. He commenced his career as station operator for the Vermont Marble Company in 1905 and became construction foreman for the General Electric Company, Schenectady, N. Y., in 1906. He was transferred, as engineer, to the company's district office in Boston, Mass., about 1910 and became assistant district engineer in 1913. In 1917 he joined the United Electric Light Company, Springfield, as electrical engineer and in 1927 was employed by the Western Massachusetts Companies. Since 1932 he had been chief engineer. **J. W. Bennett** (A '26, M '29) assistant chief electrical engineer, succeeds Mr. McKearin. Mr. Bennett was commercial engineer for the Central Hudson Gas and Electric Company, Newburgh, N. Y., in 1924 and joined the Eastern New Jersey Power Company, Asbury Park, as distribution engineer in 1925. In 1930 he was made distribution engineer for the Western Massachusetts Companies and in 1939 was appointed assistant chief electrical engineer.

A. L. Cook (A '02, M '13) director of the school of science and technology, Pratt Institute, Brooklyn, N. Y., has retired. Mr. Cook holds the degrees of bachelor of science (1901) and master of science (1903) from Worcester Polytechnic Institute. He was associated first with Pratt Institute as instructor in charge of the electrical laboratory from 1903 to 1907. After serving as electric power engineer for Westinghouse, Church, Kerr and Company, New York, N. Y., from 1907 to 1913, he returned to Pratt Institute as head of the electrical department. In 1938 he became director of the school of science and technology. He is the author of several textbooks and a member of the Society for the Promotion of Engineering Education.

H. V. Erben (M '43) formerly manager of the central station divisions, General Electric Company, Schenectady, N. Y., has been elected a commercial vice-president. A graduate of the Sheffield Scientific School, Yale University, Mr. Erben joined the General Electric Company in 1917. After service with the United States Army he entered the testing department in 1920 and in 1922 was transferred to the lighting engineering department. He was made section head of the apparatus division in 1923, assistant to the manager of the division in 1928, and manager in 1929. He was appointed manager of switchgear sales in 1933 and assistant manager of the central-station divisions in 1939. In 1941 he became manager.

H. J. Gille (A '01, M '13) manager of industrial and agricultural development, Puget Sound Power and Light Company, Seattle, Wash., recently retired. Mr. Gille entered the electrical field in 1890 when he was employed by the Acme Electric Company, St. Paul, Minn., and in 1898 became general superintendent of the Edison Electric Light and Power Company, St. Paul. He joined the Minneapolis General Electric Company, St. Paul, in 1907 and the Puget Sound Company in 1913 as general sales manager. In 1932 he was made manager of industrial and agricultural development.

R. C. Faught (A '19) sales engineer, General Electric Company, Baltimore, Md., has retired. Mr. Faught was graduated from the Massachusetts Institute of Technology in 1894 and entered the employ of the General Electric Company in 1898 as test man. Since 1900 he has been engaged in sales engineering. He was stationed in Philadelphia, Pa., in 1900, in Richmond in 1902, and in Baltimore in 1903. Except during World War I when he had charge of the company's Washington, D. C., office, he has remained at Baltimore since.

OBITUARY ● ● ● ●

Stephen S. Darrall (A '41) member of the United States Merchant Marine was reported lost at sea in September 1943. Mr. Darrall, who was born August 29, 1882, in Irwin, Pa., commenced electrical work as an engineering apprentice for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1902 and was transferred to New York, N. Y., to do construction, erection, and electrical servicing in 1904. Going to Iniwue, Chile, in 1907 he was employed in electrical engineering, sales, and construction for J. K. Robinson, Westinghouse agent in Chile, Peru, Bolivia, and Ecuador. He served aboard the S.S. *Minnesota* in 1914 before entering the employ of the Kennecott Corporation, Latouche, Alaska, as chief electrician. As chief electrician he also worked for the Pacific Coast Gypsum Company, Gypsum, Alaska, from 1917 to 1919. In 1919 he entered the district service department of the Westinghouse company, in Seattle, Wash. He was superintendent of electrical construction for the Long Bell Lumber Company, Longview, Wash., from 1923 to 1925 and for the San Francisco Mines of Mexico, Parral, Chihuahua, Mex., in 1926 and 1927. Returning to the United States he was employed in the district service department of the General Electric Company in 1928 and of the Westinghouse Company in 1929. From 1931 to 1941 he was employed at various engineering projects, mechanical and civil as well as electrical. In 1941 he was employed on the national defense program at the Boston Yards of the United States Navy. He resigned in 1943 to join the merchant marine.

William McNichol Eglinton (A '03) second-hand-machinery and fire-insurance broker, Santiago, Chile, died August 4, 1943. He was born May 14, 1867, in Glasgow, Scotland, and gained his electrical training in the experts course of the Thomson-Houston Electric Company in 1888 and 1889 and in the student course of the General Electric Company at Schenectady, N. Y., and Lynn, Mass., in 1899. From 1889 to 1893 he worked as draftsman and foreman in Venezuela and in 1893 joined the Maracaibo (Venezuela) Electric Light Company as chief engineer and electrician. In 1901 he became constructing engineer and technical director for the South Puerto Rican Sugar Company. Later he was associated with the Electric Company of Concepcion (Chile) until 1910. For a time he was consulting and constructing engineer in New York, N. Y., and in 1912 was employed as engineer by the International Machinery Company, Santiago, Chile. He became manager of the Industrial Supplies Company, Santiago, in 1920 and manager of the machinery department, Errazuriz Simpson and Company, Ltd., Santiago. From 1926 to 1929 he was sales engineer for Wassel, Duval and Company, Santiago, and for the Allis-Chalmers Manufacturing Company from 1929 to 1936. He established a consulting practice in 1936 and a brokerage in 1940.

Cyril Cochrane Levy (A '33) industrial engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and 1943–44 chairman of the AIEE committee on electrochemistry and electrometallurgy, died June 5, 1944. Mr. Levy was born September 18, 1886, in Lucea, Jamaica, B. W. I., and attended Toronto University. His first position in the electrical industry was switchboard operator for the New York (N. Y.) Edison Company in 1905 and 1906. During 1912–13 he worked as electrical draftsman for the Canadian General Electric Company, Toronto, Ont. As switchboard draftsman he joined the Westinghouse Company in 1913 and from 1916 to 1920 he was designing engineer in the switchboard department. In 1920 he was placed in charge of switchboard drafting and in 1922 became automatic switching engineer. Since 1930 he has been engaged in application engineering specializing in electrochemical and chemical industries. Mr. Levy had served on the committee on electrochemistry and electrometallurgy since 1934 and held the committee chairmanship for 1940–41. He was a member of the Electrochemical Society.

Harold Leonard Smith (M '36, F '42) chief engineer, the Louis Allis Company, Milwaukee, Wis., died April 7, 1944. Born in Niles, Mich., October 16, 1890, Mr. Smith received from Michigan State College the degree of bachelor of science in 1914 and the degree of electrical engineer in 1920. As a graduate student he studied under Benjamin J. Lamme at the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1914. Named design engineer in 1915, he entered the United States Navy in 1918 and in 1919 returned to the Westinghouse Company to work on induction motor design. He joined the Howell (Mich.) Electric Motors Company in 1920 as resident engineer and in 1921 joined the Mechanical Appliance Company, Milwaukee, which later became the Louis Allis Company. Within a year he was given the title of chief engineer. Mr. Smith served on many committees of the National Electrical Manufacturers Association and was a member of the Engineers Society of Milwaukee. A number of patents were issued to him.

William deYoung Kay (A '16) treasurer, Lane Cotton Mill Company, New Orleans, La., died January 31, 1944. Mr. Kay, who was born in Memphis, Tenn., November 24, 1891, was graduated from Massachusetts Institute of Technology in 1913. From 1913 to 1919 he was employed by the Edison Electric Illuminating Company of Brooklyn (N. Y.) as salesman and power engineer. After a short association with the Franklin Baker Company, New York, N. Y., he became president of the United Vegetable Oil Refinery, Inc., New York, in 1920. He was partner and president of Kay and Ellinger, New York, from 1924 to 1926, dissolving this partnership to become vice-president of Nathan Straus and Sons, Inc., New York. Employed as a broker and member of the New York Stock Exchange from 1928 to 1936, he also was associated with Halle and Steiglitz, New York, from 1929 to 1931. He was partner in Kay, Byfield and Company, New York, from 1936 to 1943. In 1943 he joined the Lane Cotton Mill Company as treasurer.

Chester M. Davis (A '43) general results engineer, traffic department, Postal Telegraph Cable Company, New York, N. Y., died April 27, 1944. He was born February 28, 1907, in Youngsville, Pa., and was graduated from the University of Pennsylvania with the degree of bachelor of science in electrical engineering in 1929. In 1930 he joined the Postal Telegraph Company, Dallas, Tex., as instructor in testing and regulating. He was made testing and regulating inspector for the company's Southwestern division in 1932 and division traffic superintendent in 1936. He was transferred to New York as general results engineer in 1938. Mr. Davis was a member of Eta Kappa Nu and Sigma Tau.

Edwin Bailey Lovewell (M '43) electrical research engineer, New Britain (Conn.) Machine Company, died in November 1943. Born January 17, 1904, in Royalston, Mass., Mr. Lovewell was graduated from Worcester Polytechnic Institute in 1926 with the degree of bachelor of science in electrical engineering. He entered the employ of the General Electric Company, Schenectady, N. Y., in 1926 as a testman and in 1928 was made industrial control design engineer. From 1929 to 1930 he was stationed in the industrial engineering department where he worked on industrial applications. In 1930 he was transferred to the company's Providence, R. I., office. He was engaged in design and application engineering for Sumner L. Willson, Hartford, Conn., from 1933 to 1942. In 1942 he joined the New Britain Machine Company. He was a member of Tau Beta Pi.

William James Sanford (A '23) commercial salesman, Florida Power and Light Company, Miami, died December 23, 1943. Born August 24, 1878, in Plymouth, Pa., Mr. Sanford commenced his career as general foreman for the Jandus Electric Company, Cleveland, Ohio, from 1899 to 1902. In 1902 he became superintendent for the Camaguey (Cuba) Electric Company. He returned to the United States and served as general manager of the Bellows Falls (Vt.) and Saxtons River Street Railway Company from 1906 to 1920. After a short period as division manager and construction engineer for the Camaguey Company from 1920 to 1924, he joined the Florida Power and Light Company as engineer in the distribution department. In 1942 he was designated commercial salesman.

C. Edward Cole (A '27) staff supervisor, long lines traffic department, American Telephone and Telegraph Company, New York, N. Y., died March 19, 1944. He was born March 2, 1884, in Wilcox, Pa., and was graduated from Stevens Institute of Technology in 1906. After holding various positions with American Telephone and Telegraph Company from 1906 to 1909, he became vice-president and chief engineer of the L. J. Wing Manufacturing Company, New York, from 1910 to 1912. He returned to the American Telephone Company in 1912 as division supervisor in the traffic department and remained in that position until 1924, serving in Atlanta, Ga., from 1916 to 1920. In 1924 he was appointed engineer in the long lines department and staff supervisor in 1940.

Lester L. Conrad (A '36, M '41) supervisor, standards laboratory, Southern California Edison Company, Ltd., Alhambra, died April 6, 1944. He was born October 26, 1888, in Pasadena, Calif., and entered the electrical field in 1910 as electrician for the Fisher Amusement Company. From 1911 to 1917 he was chief electrician for the Clunes Theaters Company and in 1917 entered the employ of the Southern California Edison Company, working on distribution until 1919. Since 1919 he had been supervisor in the standards laboratory. He was a past chairman of the meter committee of the Pacific Coast Electrical Association.

Daniel L. Humm (A '41) New York, N. Y., died in the crash of a United States Navy plane, April 10, 1944. He was born January 14, 1910, in Earlville, Ill., and received the degree of bachelor of science in electrical engineering from the University of Illinois in 1934. He was employed as testing engineer by the McIntosh Electrical Corporation, Chicago, Ill., from 1935 to 1937 and in 1937 joined the Illinois Testing Laboratories, Inc., Chicago, as sales engineer.

Leslie S. Carpenter (A '20) engineer, Chenango and Unadilla Telephone Corporation, Norwich, N. Y., died April 20, 1944. He was born October 27, 1879, in Fletcher, Vt., and attended the University of Vermont. He entered the employ of the New York Telephone Company in 1910 and was named assistant engineer in 1922. From 1927 to 1943 he was associated with the New Jersey Bell Telephone Company as electrical engineer and in 1943 joined the Chenango and Unadilla Telephone Corporation.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting on June 15, 1944, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Clingerman, B. H., chief elec. engr., Northern States Power Co., Minneapolis, Minn.
Codding, H. W., asst. engr., Public Service Elec. & Gas Co., Newark, N. J.
Corney, C. A., asst. vice-president and supt. of engg., Boston Edison Co., Boston, Mass.
Forbes, H. C., asst. vice-president, Consolidated Edison Co. of N. Y., Inc., New York
Haines, T. H., asst. vice-president of engg., Boston Edison Co., Boston, Mass.
Hejda, C. J., chief testing engr., Commonwealth Edison Co., Chicago, Ill.
St. Clair, H. P., system planning engr., American Gas & Electric Service Corp., New York
Thomas, R. L., vice-president, Consolidated Gas Elec. Lt. & Pwr. Co., Baltimore, Md.

8 to grade of Fellow

To Grade of Member

Albach, C. R., asst. engr., U. S. Engineer Office, Buffalo, N. Y.
Baker, E. F., elec. engr., Packard Motor Car Co., Detroit, Mich.
Bechlund, O. A., associate engr., Univ. of California, San Diego, Calif.
Berman, Samuel, associate director, Waugh Labs., New York
Beyette, C. K., elec. engr., Texas Electric Service Co., Fort Worth, Texas
Breslauer, N. P., research engr., Allen Bradley Co., Milwaukee, Wis.
Brown, R. P., equipment engr., Southwestern Bell Tel. Co., Dallas, Texas
Burley, J. G., district engr., Bell Tel. Co. of Canada, Toronto, Ont.
Carson, R. B., asst. managing engr., Canadian General Elec. Co., Toronto, Ont.
Coxe, E. H., elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Cross, P. C., application engr., General Elec. Co., Kansas City, Mo.
Culver, D. N., transmission engr., Bell Tel. Co. of Canada, Toronto, Ont.
Ding, A. P., engr., U. S. Engineers, Portland, Ore.
Everest, F. A., engr., Univ. of California, San Diego, Calif.
Gray, W. F., associate prof. of elec. engg., Texas Technological College, Lubbock, Texas
Hansen, N. J., sales engr., Moloney Elec. Co., Chicago, Ill.
Hearson, L. T., engr., American Tel. & Tel. Co., Chicago, Ill.
Heath, E. A., asst. engr., Kansas Gas & Elec. Co., Wichita, Kansas
Hendrickson, E. R., division operating supt., Public Service Co. of Illinois, Glencoe, Ill.
Holt, C. B., asst. prof. of elec. engg., Pennsylvania State College, State College, Pa.
Johnson, A. A., Central Station engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Jones, H. L., associate prof. of elec. engg., University of New Mexico, Albuquerque, N. M.
Leffell, W. O., instructor in elec. engg., University of Tennessee, Knoxville, Tenn.
Lerstrup, K., elec. engr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Mencher, I., elec. engr., Emerson-Garden Elec. Co., Elizabeth, N. J.
Nudd, P., asst. prof. in elec. engg., Cooper Union, New York
Rice, I. S., asst. engr. of maintenance, Commonwealth Edison Co., Chicago, Ill.
Ringland, W. L., elec. engg., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Robbing, C. F., supervising engr., Cutler-Hammer, Inc., Milwaukee, Wis.
Rogers, E. W., overhead lines engr., Dallas Power & Light Co., Dallas, Texas
Rosch, J. M., engr., Curtiss Wright Airplane Corp., Robertson, Mo.
Schultz, H. G., senior engr., Commonwealth Edison Co. Chicago, Ill.
Sharpe, J. M., asst. supt. of operation, Shawinigan Water & Power Co., Shawinigan Falls, Que., Can.
Sherry, W. H., elec. engr., Ferguson Elec. Construction Co., Buffalo, N. Y.
Spence, B. G., division elec. engr., Oklahoma Gas & Elec. Co., Enid, Okla.
Steiner, H. C., section leader, General Elec. Co., Schenectady, N. Y.
Strelzoff, J. A., associate prof. of elec. engg., Michigan State College, E. Lansing, Mich.
Volckmann, E., junior maintenance engr., New York City Transit System, New York
Warner, E. S., senior plant draftsman, Commonwealth Edison Co., Chicago, Ill.
Wasserman, C., asst. to elec. engr., Consolidated Gas Elec. Lt. & Pwr. Co., Baltimore, Md.
Watson, J. L., meter tester, Portland General Elec. Co., Portland, Ore.
Wright, F. T., asst. elec. engr., Underwriters Labs., Inc., New York

42 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objectiong to the election of any of these candidates should so inform the national secretary before July 31, 1944, or September 30, 1944, if the applicant resides outside of the United States or Canada.

To Grade of Member

Bacon, F. E., Bacon Elec. Co., Chillicothe, Ill.
Carleton, H., David Taylor Model Basin, Carderock, Md.
Coker, G. W., Burge & Stevens, Atlanta, Ga.
Condon, E. U., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Coyle, A. B., Line Material Co., Los Angeles, Calif.
Duguid, J. M., Bell Telephone Labs., New York, N. Y.
Duncan, J. A., Jr., American Tel. & Tel. Co., New York, N. Y.
Fidler, I. (Reelection), N. C. Shipbuilding Co., Wilmington, N. C.
Finlayson, H. M., Shawinigan Water & Pr. Co., Montreal, Que., Can.
Fleshman, B. A. (Reelection), Cities Serv. Ref. Corp., Lake Charles, La.
Freitag, R. A., Willamette Iron & Steel Corp., Portland Oreg.
Fulton, W. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ginocchio, J. A. (Reelection), Rust Engineering Co., Front Royal, Va.
Gray, R. W., Mountain States Tel. & Tel. Co., Denver, Colo.
Halbach, E. A. (Reelection), Marquette Univ., Milwaukee, Wis.
Harkness, J. R., General Elec. Co., Schenectady, N. Y.
Hinsberger, J. F., City of Santos Imps. Co. Ltd., Vila Matias, Brazil, S. A.
Holloway W., Major, U. S. Army, Ocean Springs, Miss.
Hutcheson, J. A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ingalls, D., Titeflex, Inc., Newark, N. J.
James, L. I. (Reelection), Southern Airways, Inc., Decatur, Ala.
Kelsey, H. D., General Elec. Co., Fort Wayne, Ind.
Kessel, R. L. (Reelection), Ill. Inst. of Tech., Chicago, Ill.
Landy, J. J., Aluminum Ore Co., East St. Louis, Ill.
Malpica, J. M., Nat. Powder Factory, Mex. Govt., Santa Fe, D. F., Mex.
McKay, R. (Reelection), Washington Water Pr. Co., Spokane, Wash.
Page, A. W., Major, Royal Engineers, London, England.
Peeples, P., Georgia Pr. Co., Atlanta, Ga.
Reed, G. L. (Reelection), Pub. Serv. Co. of Northern Ill., Chicago, Ill.
von Herrmann, C. F., Jr., Captain, U. S. Army, Birmingham, Ala.
Waggoner, R. M., Hubbard & Co., Chicago, Ill.
Wright, H. P., B. & O. R.R. Co., Baltimore, Md.

32 to grade of Member

To Grade of Associate

United States and Canada

1. NORTH EASTERN

Johnston, J. W., Westinghouse Elec. & Mfg. Co., Boston, Mass.
Lee, W., Raytheon Mfg. Co., Waltham, Mass.
Percival, D. R., Norton Co., Worcester, Mass.
Plummer, C. H., Chicopee Mfg. Corp., Chicopee Falls, Mass.
Topliffe, C. V., Cutler-Hammer, Inc., Boston, Mass.

2. MIDDLE EASTERN

Boone, D. R., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Colado, R. E., General Elec. Co., Cincinnati, Ohio
Edge, D. R., Central Electric Coop., Inc., Parkers Landing, Pa.
Happold, H. H. (Re-election), Edward G. Budd Mfg. Co., Philadelphia, Pa.
Law, G. G., Dayton Pr. & Lt. Co., Dayton, Ohio
Lewis, C. B., General Elec. Co., Erie, Pa.
Mauk, G. S., Apex Elec. & Mfg. Co., Cleveland, Ohio
Myers, O. C., Mennonite Central Comm., Akron, Pa.
Prescott, R. S., Naval Ordnance Lab., Washington, D. C.
Rhodes, W. H., Chesapeake & Potomac Tel. Co., Washington, D. C.
Steinhilber, W. B., Electrical Contractor, Ashland, Pa.
Thorbahn, T. S., American Tel. & Tel. Co., Philadelphia, Pa.
Towne, R. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Wickey, J. R., Clark Controller Co., Cleveland, Ohio
Woodward, B., General Elec. Co., Erie, Pa.

3. NEW YORK CITY

Castronuovo, A. J.. Gibbs & Cox, Inc., Kearny, N. J.
Dear, J. A., Federal Shipbuilding & Drydock Co., Newark, N. J.
Dowsley, R. E., Sperry Gyroscope Co., Brooklyn, N. Y.
Gully, E. J., Todd Shipyards Corp., Hoboken, N. J.
Hammann, R. T. (Reelection), New York Dock Co., Brooklyn, N. Y.
Kral, A., M. W. Kellogg Co., New York, N. Y.
Marks, J. A., Jersey Central Pr. & Light Co., Allenhurst, N. J.
McSherry, L. K., Smith-Meeker Engr. Co., New York, N. Y.
Moerschell, G. E., College of City of N. Y., New York, N. Y.
Race, C. R., Arma Corp., Brooklyn, N. Y.
Rallis, G., John A. Kiamos, Inc., New York, N. Y.
Safonoff, M., Moran, Proctor, Freeman & Mueser, New York, N. Y.
Sands, P. J. (Reelection), U. S. Navy Yard, New York, N. Y.
Scarborough, H. B., Federal Tel. & Radio Labs., New York, N. Y.
Vanora, J. A., M. W. Kellogg Co., New York, N. Y.
Whelan, R. L. J., New York Technical Institute, New York, N. Y.
Young, B. B., Lawrance Aeronautical Corp., Elizabeth, N. J.

4. SOUTHERN

Bell, T. J., Carolina Pr. & Lt. Co., Raleigh, N. C.
Brady, D. E., Jr., Carolina Alum. Co., Badin, N. C.
Colli[illegible], M. M., General Elec. Co., Birmingham, Ala.
Gallant, W. M. (Reelection), Westinghouse Elec. & Mfg. Co., Raleigh, N. C.
Hicks, E. B., Carolina Pr. & Lt. Co., Raleigh, N. C.
Meador, J. T., Southern Elec. Serv., Charlotte, N. C.
Richardson, J. M., Girdler Corp., Louisville, Ky.
Settoon, L. L. (Reelection), East Louisiana State Hospital, Jackson, La.
Smith, E. J., U. S. War Dept., Atlanta, Ga.
Stockwell, H. L., Turner Elec. Works, Jacksonville, Fla.
Travis, J. W., Southern Bell Tel. & Tel. Co., Knoxville, Tenn.
Trout, F. I., Tupelo Water & Light Dept., Tupelo, Miss.
Wellborn, J. M. (Reelection), Rotary Lift Co., Memphis, Tenn.
Westbrook, W. L., Georgia Pr. Co., Columbus, Ga.
Wilson, J. C., Jr., Board of Pub.Util., Athens, Tenn.
Woodd, G. B., Sr., U. S. Naval Operating Base, Key West, Fla.

5. GREAT LAKES

Bratu, N., Bodine Elec. Co., Chicago, Ill.
Dorsey, J. M., Univ. of Chicago, Chicago, Ill.
Gallatin, P. M., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Grant, G., III, Dow Chemical Co., Midland, Mich.
Greenspon, W., Detroit Pub. Lighting Comm., Detroit, Mich.
Herman, C. J.. General Elec. Co., Fort Wayne, Ind.
King, J. J., General Elec. Co., Jackson, Mich.
Kiehn, R. A., Commonwealth Edison Co., Chicago, Ill.
Kolderman, R. W., Dow Corning Corp., Midland, Mich.
Nejedlo, D., Allen-Bradley Co., Milwaukee, Wis.
Schahfer, R. M. (Reelection), Northern Ind. Pub. Serv. Co., Hammond, Ind.
Splees, H. A., General Elec. Co., Fort Wayne, Ind.

7. SOUTH.WEST

Benjamin, K. U., Beech Aircraft Corp., Wichita, Kans.
Bruemer, H. H., Jr., Moloney Elec. Co., St. Louis, Mo.
Combs, G. U., Socony Vacuum Oil Co., Augusta, Kans.
Corporon, E. K., Kans. Gas & Elec. Co., Wichita, Kans.
Crafton, W. L., Arkansas-Missouri Pr. Corp., Blytheville, Ark.
Garrison, C. A., Cessna Air Craft Co., Wichita, Kans.
Granich, G. F., Moloney Elec. Co., St. Louis, Mo.
Haun, J. C., International Min. & Chem. Corp., Austin, Texas
Irving, W. S., General Elec. Co., Wichita, Kans.
Johnson, C. V., Beech Aircraft Corp., Wichita, Kans.
Longstaff, R., Kans. Gas & Electric Co., Wichita, Kans.
Lucy, C. C., Radio Station KANS, Wichita, Kans.
Martin, R. H., Boeing Aircraft Co , Wichita, Kans.
Miner, J. T., U.S.N.R., Corpus Christi, Texas
Moore, R. E., Kans. Gas & Elec. Co., Independence, Kans.
Norris, J. M., Kans. Gas & Elec. Co., Wichita, Kans.
Patton, W. S., James R. Kearney Corp., St. Louis, Mo.
Rosenthal, J., Humble Pipe Line Co., Houston, Texas
See, P. G., Consolidated Vultee Air Corp., Fort Worth, Texas

8. PACIFIC

Aiken, W. R., Permanente Metals Corp., Richmond, Calif.
Binnings, G. F., Marinship Corp., Sausalito, Calif.
Flenner, A. C., U. S. Navy Yard, Mare Island, Calif.
Inman, B. D., Sr., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Jenkins, I. G., Jr., Central Arizona Lt. & Pr. Co., Phoenix, Ariz.
Kerber, D. L., Univ. of Calif., Berkeley, Calif.
Maxwell, L. G., U. S. Navy, San Francisco, Calif.
Niemoeller, E. (Reelection), Southern Calif. Tel. Co., Los Angeles, Calif.
Otis, P. H., San Diego Gas & Elec. Co., San Diego, Calif.
Redmond, J. E., J. E. Redmond Co., Phoenix, Ariz.
Ryer, L. M., Kaiser Co., Oakland, Calif.
Sunderland, R. C., Consolidated Vultee Aircraft, San Diego, Calif.
Younger, F. W., U. S. Navy Yard, Mare Island, Calif.

9. NORTH WEST

Condit, J. M., Associated Shipbuilders, Seattle, Wash.
Doull, A. G., Mountain States Tel. & Tel. Co., Great Falls, Mont.
Eminger, W. D., Montana Pr. Co., Great Falls, Mont.
Hansen, M. O., Montana Pr. Co., Great Falls, Mont.
Johnson, D. A., Mountain States Tel. & Tel. Co., Great Falls, Mont.
Klockler, W. C., Montana Pr. Co., Great Falls, Mont.
Kraft, W. R., Bonneville Pr. Adm., Portland, Oreg.
Mangan, J. J., Bonneville Pr. Adm., Eugene, Oreg.
Reid, R. A., Montana Power Co., Great Falls, Mont.
Richardson, W. D., Montana Pr. Co., Great Falls, Mont.
Staff, C. H., U. S. Army Engns., Seattle, Wash.

10. CANADA

Barbour, C. A., D. M. Fraser, Ltd., Montreal, Que., Can.
Edwards, F. C. N., Northern Elec. Co. Ltd., Regina, Sask., Can.
Eull, L. F., Lieut., R.C.N., Halifax, N. S., Can.
Finch, G. H., Canadian Westinghouse Co., Ltd., Ottawa, Ont., Can.
Mather, R. H. (Reelection), Shawinigan Water & Pr. Co., Montreal, Que., Can.
Streeter E. R. (Reelection), Sorg Pulp Co., Ltd., Port 'Mellon, B. C., Can.

Elsewhere

Boutacoff, A. A., Mount Isa Mines Ltd., Mount Isa, Aust.
Heeley, F. S., R.A.F., London, England
Jones, E., English Elec. Co., Bradford, England
Race, A. B., British Thomson-Houston Co. Ltd., Manchester, England
Salama, G., Western Gharbia Pumping Stations, El Buseili, Rosetta Line, Egypt

Total to grade of Associate
United States and Canada 114
Elsewhere 5

OF CURRENT INTEREST

Performance of New Walkie-Talkie in Anzio Action Praised

In its baptism of fire in the Anzio beachhead assault the latest Signal Corps "walkie-talkie" or SCR 300 radio set met and exceeded every expectation for range and reliability and was lauded as the most valuable item of radio equipment in the attacking division by the division signal officer.

The SCR 300 set, omnipresent at the Anzio landing, was used in all radio nets from division to infantry companies as well as in Cub observation planes and afterwards was termed the most successful instrument yet devised for amphibious communications. Its range is triple that of the former "walkie-talkie," and it has remarkable clarity of tone attained through frequency modulation which eliminates static. Netting of the sets on one frequency is facilitated by the substitution of the superheterodyne for the superregenerative receiver. An extra goose-neck-type antenna supplements the standard vertical antenna of such sets. This permits transmission even when the operator is prone on the ground. A headset for the operator and a handset for the officer in command accompany the new model. Miniature radio tubes prolong the life of its batteries and add to its compactness. The set is treated to withstand rain and immersion in water for short periods. Although the new model weighs 35 pounds, as did the older one, its portability is enhanced by an extra strap which encircles the soldier's waist and distributes the set's weight more evenly.

First Telephone Sets Since 1942 Ready for September Production

Resumption of the manufacture of civilian telephone sets which ceased completely in 1942 has been authorized by the War Production Board. Priority in obtaining the annual output of 800,000 sets will be given by the communications division of the Office of War Utilities to the regions most urgently in need of them.

The restriction on the manufacture of the sets was lifted as a war measure to supply essential users, and no general distribution to private persons will be made until all essential needs have been filled. Delivery of the first sets, expected to occur in the late fall, probably will be assigned to the Pacific Coast area where the great industrial expansion caused by the war has been handicapped by a dearth of telephone facilities.

To meet its quota of 80 per cent of the released orders, the Western Electric Company has leased for three years an eight-story plant in St. Paul, Minn., formerly devoted to the manufacture of sporting goods. The plant will be equipped by reinstallation of dismantled machinery from the company's Hawthorne plant, Chicago, Ill., which in common with the company's other plants at present is in full operation fulfilling Government contracts. The company pointed out that this expansion of its facilities will not necessitate any new construction. Production is scheduled to begin in September 1944 with a working force of 1500. Availability of labor supply was a factor in leasing the property in St. Paul.

POSTWAR • • • • •

Postwar Horizons for Plastics Sighted by Scientists

A civilian's preview of four new plastic materials, now employed almost exclusively in military and naval equipment, but expected to compete with steel, wood, and other prime materials in the postwar economy, was conducted recently in New York, N. Y., by the Westinghouse Electric and Manufacturing Company. At the luncheon held in conjunction with the demonstration of Fostorite, Micarta 444, preformed plastic, and a synthetic insulating resin, the men most closely associated with the development of each described the events behind that development.

J. A. Hutcheson, associate director of the Westinghouse Research Laboratories, focused attention on the scientist's and engineer's view of research in plastics. Their viewpoint is directed toward producing a material which can perform a function better than any other material in existence rather than toward producing a mere substitute or ersatz material, according to Doctor Hutcheson. He explained his company's pre-eminence in the plastics field as a logical outgrowth of its manufacture of electrical products. The company needed, he stated, an electrical insulating material with good structural properties. Though the original impetus to the recent advances in plastics came from wartime scarcities and problems, he forecast that even when a more normal flow of raw materials is restored plastics would compete with the older materials on a strictly utilitarian basis. Their decorative qualities or novelty will not be the primary reason for any postwar expansion, he asserted.

Fostorite, an entirely new impregnating material, and a synthetic resin which substitutes for shellac—both fostered by war needs—were described by C. F. Hill (F '39) manager of the Westinghouse Company insulation department. Developed as an impregnant for standard electrical equipment, Fostorite has solved the problem of effectively moisture-proofing radio, radar, and other communication equipment in the excessively humid atmospheres of tropical climates. Usable without a solvent, Fostorite effects a 100 per cent filling of all space within the insulation. During the impregnation of the coil or device, the impregnant is in a liquid state, but the solvent reacts with another resin dissolved in it, and the whole mass turns to a durable solid. There are no by-products to the reaction that must escape. Though Doctor Hill was unable, for military reasons, to reveal the chemical composition of Fostorite, he mentioned the facts that the complete filling allows much higher-voltage gradients which in turn permits a radical reduction in size and weight of equipment so protected. Moreover the elimination of voids in coils increases the heat conductivity of the structure. Experiments show that it is insoluble in transformer oil as well as water resistant as a coating.

In describing the new synthetic resin Doctor Hill declared that this substitute developed to replace the shellac supply cut off by the war in India ultimately will prove superior to the original material. The tensile strength of fiber-glass bonded with the synthetic resin exceeds that of cast iron or sheet brass and equals that of many steels. The resin appears to be an improvement over natural shellac with its many impurities for use in commutators and electrical insulation, he said. It now promises to eliminate not only shellac but also mica, its companion material in commutators.

The preformed plastic, which is the latest answer to the question of how to combine the great strength of laminated plastics and the more complex shapings hitherto possible only in brittle plastics, was introduced by A. A. Bates. As Doctor Bates defined the problem, the researchers set out to embody the ductility as well as the strength of metals in a single plastic substance. The resulting preformed plastic first materializes as a mixture of wood pulp, water, and a phenolic resin. This is strained by a suction device against a copper-gauze shape of the finished product. The thickness of the end product is controlled by the length of the suction process collecting the fibrous mass around the copper-gauze shape. This preformed plastic piece finally is molded by heat and pressure as any other plastic. The new plastic has been employed successfully in airplane tail fillets and experimentally for airplane propeller hubs.

The story of another war-born technique for stretching the hot plastic material known as Micarta, which is the leading plastic now used for industrial application, was related by E. R. Perry, manager of the Westinghouse Micarta department. Since the war, the new process has enabled the fabrication of complicated shapes from this laminated plastic formerly economically applicable only to shapes derived from such forms as plate, rod, tubes, angles, and channels. War production called for the fashioning of intricate shapes with a minimum of tool steel. Although laminated phenolic was believed for many years to be inert at temperatures below decomposition, recent experiments revealed a stage (at 275 degrees Fahrenheit) of considerable flexibility. When Micarta so treated was cooled to normal temperatures, its average physical properties were recovered. As a result wing-gun ammunition feeds, bomb racks, fuselage tail-wheel housings and aviators' chart cases are being manufactured from the new Micarta 444. Doctor Perry reported that a one-inch bar of the material will stand a tensile pull of 13,000 pounds and can carry a compression load of 30,000 pounds without cracking. At temperatures as high as 170 degrees Fahrenheit, it will not wilt and even gains in impact strength. This strong lightweight decorative material is expected to influence the fields of furniture, lighter railroad car, and automobile manufacturing after the war.

Proposed Postwar Unemployment Compensation Plan

A plan for withholding a percentage of present war-production profits for the postwar benefit of returning veterans and unemployed war workers was outlined recently by Willard F. Rockwell, chairman of the board, Timken-Detroit Axle Company and Standard Steel Spring Company. Presented as a contribution to postwar planning, it is designed to promote a measure of security for both labor and industry in the economic upheaval that will follow contract terminations.

The six basic points of the "Rockwell plan" are:

"1. Every company engaged in whole or substantial part with war production be permitted to withhold from 1943–44 and 1945 gross income, after taxes and normal profit, and before renegotiation, a sum up to the equal of one average week's wage or salary for each month of continuous employment of each person on the payroll, with a maximum total equal to 24 weeks' wage or salary for employees who have worked two years or more.

"2. Based upon the same formula, an equal sum to be withheld for each ex-employee now serving in the Armed Forces, with the same maximum and minimum withholdings operative.

"3. These funds shall be held by each company. A complete record of such withholdings, together with the record of each active employee, plus those serving in the Armed Forces, shall be sent to the Social Security Board. Payments out of the fund shall also be recorded with the Social Security Board. These records shall be available to the public.

"4. Disbursements of these funds to unemployed workers will start at the time of complete cancellation of war contracts. Or in the instance of graduated contract cancellations due to readjustments in the war-production program, a joint labor–management committee in each plant shall determine the mutually satisfactory point at which disbursements shall start. In the case of ex-employees returning from the Armed Forces, payment shall start upon personal application of each ex-employee.

"5. Disbursements are to be made at a rate in conformity with the maximum and minimum established by state or Federal governments for unemployment compensation, until

(*a*). A job of comparable skill and compensation as last held shall be made available to each person entitled to these benefits, or

(*b*). Until such time as the total benefits accruing to each individual employee are completely disbursed, or

(*c*). Until other employment is obtained by each person entitled to these benefits.

"6. At the end of two years after complete settlement of all terminated war contracts, all withheld funds not disbursed by the companies operating under this plan shall be paid to the Federal government."

In addition, the plan includes a recommendation that the Government establish a board of business men to survey the complicated surplus-property and production-facility inventories now under the control of government procurement agencies for the purpose of recommending immediate steps to reduce these surpluses so as not to dislocate the national economy when the war ends.

Colonel Rockwell, who is also chairman of the board and president of the Pittsburgh Equitable Meter Company and chairman of the boards of the Hupp Motor Company and the Merco-Nordstrum Valve Company, has petitioned President Roosevelt and Congress for permission to institute this postwar plan in his own companies.

CED Publishes First Study on Postwar Economy Problems

The research program of the Committee for Economic Development, which represents a comprehensive study on postwar economy problems by businessmen and economic experts, recently published its first survey, "Production, Jobs, and Taxes," by Harold M. Groves, professor at the University of Wisconsin. The book is a survey of the federal tax structure, with recommendations for a postwar tax program that will be conducive to high levels of peacetime production and employment. It is the first of some 20 research studies now under way or projected by the research committee of CED.

Included in the subjects being studied are:

Liquidating war production.
Removing wartime economic controls.
Financing the reconversion and expansion of business.
Man-power demobilization and re-employment.
Providing for transition unemployment.
Money and banking policy during the transition.
Agriculture after the war.
International economic relations in the postwar world.

Chairman of the research committee of businessmen is Ralph E. Flanders, president of the Jones and Lamson Machine Company. Chairman of the research advisory board of social scientists is Professor Sumner H. Slichter of Harvard University, Cambridge, Mass. Theodore Yntema, professor of economics on leave from the University of Chicago, Ill., is director of the staff of economists.

Rivalry for Postwar Control of World-Wide Communications

The United States Government is planning now to gain a share in control of the world's system of postwar communications, according to a recent article in the *United States News*. International communications in the past have been dominated by Great Britain, and lower rates have been given to British, Canadian, Australian, and other Empire businessmen than are available to people of the United States communicating with persons in the British Empire. The British maintain a flat rate of 30 cents per word for cablegrams and radiotelegrams between any two points in the Empire, whereas rates to residents of the United States in some instances may exceed one dollar per word.

Congress will be asked to shape a new policy for American communications companies, in order that the United States may enter into discussions on matters of rate control and service restrictions.

INDUSTRY● ● ● ● ●

Military and Postwar Radio in Russia Discussed by Ellis

Speaking on "Radio in Russia" before the third War Production Conference and the 20th annual membership meeting of the Radio Manufacturers Association in Chicago, Ill., June 6, 1944, Ray C. Ellis, director of the radio and radar division of the War Production Board, described his impressions gained during a six-week intensive study in Russia of Soviet electronic-equipment requirements.

Mr. Ellis visited representative radio factories in Moscow and the Ural region, and observed development trends, types and quantities of products being manufactured, and organization and facilities. Purpose of the visit was to discuss with Soviet engineers and factory managers their military electronic situation in relation to their production and our assistance as well as to discuss plans for closer working arrangements in the radio field both now and after the war.

As compared with the radio industry in the United States, Mr. Ellis found that of Russia prior to the war quite small. Home and apartment installations used loud-speakers each with a volume control which were connected to a centrally operated receiver. Because of small production, hand methods, and lack of suitable transportation, most of the 15 factories producing radio sets made all of their own parts except the tubes and loud-speakers. There was no standardization of parts, and the factories did very little development work themselves because the design and development of new models originated with a central government planning agency.

What research and development was in progress was set up separately from the factories, Mr. Ellis reported, and was associated with the universities at Leningrad and Moscow, and with the National Academy of Sciences in Moscow. The programs consisted mostly of work on high-powered transmitters, television, and special tubes, with little concentration on receiving tubes, short-wave sets, high fidelity, frequency modulation, loud-speakers, or component parts. There were two experimental television stations in operation.

Foreign contact by Russian engineers was kept to a minimum, even before the '30's. That permitted was limited largely to representatives of the Radio Corporation of America, some German assistance in Leningrad on tubes, and some English help on a loud-speaker plant.

When Germany invaded Russia in June 1941, all of the radio industry had to be evacuated, under extremely adverse conditions, from locations in the west to central Siberia, Mr. Ellis explained. Although much of the work after the invasion was conducted under extremes of weather and warfare hazards, many of which still prevail, he found that the factories had all the elements of a modern plant, and that both production and morale were at a high level.

Mr. Ellis reported that entire plants are on a quota basis, with production results posted every ten days. All radio-factory employees are on an incentive basis, with the total weekly pay check dependent upon their rate of production. Workers in departments other than production are awarded medals for outstanding performance, which they proudly wear and which also entitle them to additional food coupons, better seats at the opera, additional gasoline for their cars, and in general provide a basis for a higher standard of living.

For postwar expansion Mr. Ellis declared that the Russians were in possession of the knowledge and ability to establish plants comparable in operating efficiency to the radio factories in the United States.

Expanded Oil Output Will Aid New Industries in Latin America

Increase in power supply is the fulcrum of industrial progress in Latin America, according to a report from a recent issue of the *United States News*. It will be accomplished largely through the development of hitherto untapped petroleum resources in Brazil, Peru, and Ecuador, and through expansion of petroleum production in Argentina and Venezuela.

Since coal has been found only in small quantities south of the Rio Grande so far, and since hydroelectric expansion, although potentially large, is a long-term program which undoubtedly will necessitate government participation, petroleum offers the immediate answer to the fuel and power problems of new Hemisphere industries. The Peruvians already have started production in the previously untapped trans-Andean region of the Amazon basin, drilling in Brazil and Ecuador has been delayed awaiting equipment held up by the war, and development in Haiti, Santo Domingo, and other countries is still in the exploratory stages.

In the meantime, production in Venezuela, whose proved resources are expected to make her the world's second oil producer, is running at almost 50 per cent above the low of 1943, caused by the shipping shortage. By the end of 1944, Venezuelan production is expected to reach 750,000 to 800,000 barrels daily. This compares with a recent high in the United States of 4,500,000 barrels a day.

One of the most interesting facts about this expansion is the mutual-assistance basis by which it will be achieved. The recent Conference of Inter-American Development Commissions urged the co-operation of the Hemisphere countries in supplying much of the necessary capital, technicians, and machinery, themselves.

Since Venezuela's Central Bank has been unable to sell importers the dollars turned in by United States oil firms to obtain bolivars for their operations, the capital for Venezuelan oil expansion will have to be supplied by national funds. The funds will be negotiated in bolivars borrowed from the Central Bank, or in gold, imported to strengthen Venezuelan reserves and to remove surplus funds from the market. Use of local funds may indicate a new trend of growing national participation in foreign-owned enterprises, and may reduce prevalent high interest rates in Latin America.

Expansion of Argentine petroleum production will influence United States–Argentine trade relationships indirectly, since increased industrialization will lessen reliance on farm exports, largely to Great Britain, to maintain Argentine economy.

High-Frequency Electric Field Used in Processing Foodstuffs

Uhlmann patent 1,992,515 entitled "Apparatus for the Preparation of Foodstuffs," available for licensing through the Alien Property Custodian, describes equipment by which raw food materials are subjected to a high-frequency induced electric field for processing. The apparatus is a wave oven which consists of a transformer coil supplied with 220 volts at 50 cycles, a secondary coil connected to a capacitor, a spark gap, and another coil that emits a high-frequency field of 800 meters or less.

The method may be used to can foodstuffs as well as to cook and preserve them. Advantages claimed are saving of time, improvement in taste, and retention of vitamins and mineral salts. Fruits can be cooked in their skins without loss of shape, and milk is freed of living organisms without heating to 100 degrees centigrade, or boiling temperature. It also may be used to brew coffee and tea, obtaining the same extraction at a maximum temperature of 70–75 degrees centigrade (169 degrees Fahrenheit) as compared with the temperature of 100 degrees centigrade when made by the usual methods.

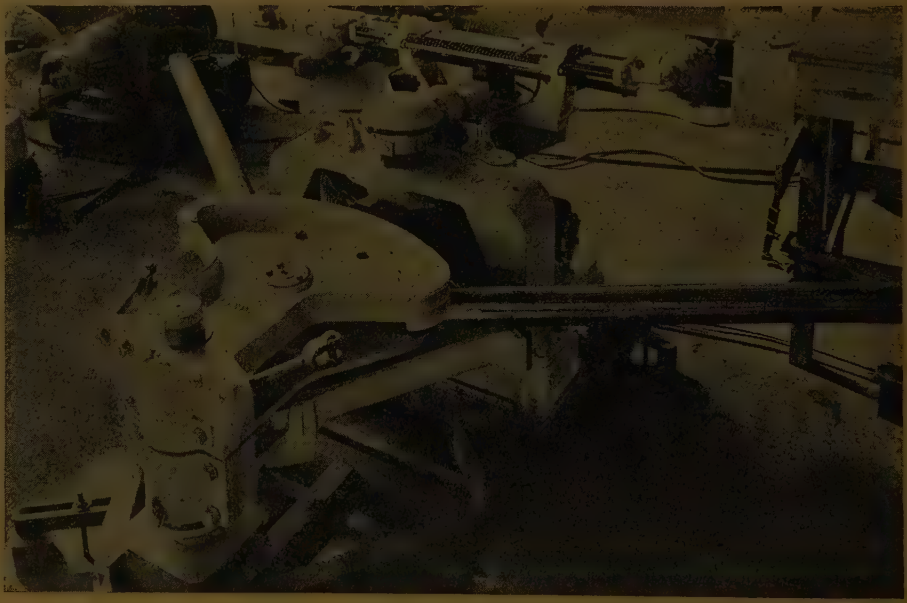
Many other inventions relating to food processing, machinery, and packaging are included in the 45,000 vested patents and patent applications which have been seized by the Alien Property Custodian from enemy aliens and nationals of occupied countries. Catalogues and class lists of vested patents may be purchased from the Alien Property Custodian, Chicago 3, Ill., or are available for public inspection, along with copies of the patents, in the Custodian's patent administration division offices in Washington, D. C., New York, N. Y., Chicago, Ill., Boston, Mass., and Portland, Oreg. Catalogues may also be consulted in the regional and field offices of the Smaller War Plants Corporation. License applications should be addressed to the Alien Property Custodian, Division of Patent Administration, Washington 25, D. C.

Electronic Sorting Table Speeds Inspection of Contact Assemblies

Much greater speed in the sorting and inspection of tiny contact assemblies produced at General Electric Company, Schenectady, N. Y., has been made possible through the development of an electronic sorting table that routes the assemblies into three different channels, depending on whether they are too high, too low, or within the tolerances.

The specially designed sorting table incorporates a new electronic relay and a factory-constructed "contact head." Each assembly is fed onto a 45-degree slide that is part of the contact head. About halfway down the slide the assembly comes to a contact point located at preset height. If the assembly touches the point, it is oversize, and the contact made closes the grid circuit of the relay's electronic tube, which in turn energizes an electromagnetic relay. A solenoid is energized next, thereby sending the assembly down a chute into a container for oversize parts. A short distance beyond the first point a second contact point is set

Navy LST Boats Steered Electrically



The extreme mobility needed by the Navy's landing stage tank craft for the successful landing of troops, often under enemy fire, is afforded by this electrically operated quadrant steering gear designed and built by the Baldwin Southwark division of the Baldwin Locomotive Works. Located below deck in a compartment just above the rudders in the stern of the craft, the gear is operated electrically by remote control from the wheel on the bridge. In case of power failure the gear can be hand-operated. The quadrant arc in which the gear swings and the long steel arms which transmit the motion of the gear to the rudders are shown here

at standard height less tolerance. Since oversize assemblies have been eliminated already, parts touching the second point are within acceptable limits and are shot down a second chute. Undersize assemblies do not touch either point and slide undisturbed into a third tray.

Previously, the contact assemblies, each almost small enough to require handling with tweezers, were sorted and inspected by hand. Each assembly was checked with a needle micrometer and then sorted accordingly.

Central Bureau Established for Rural Electrification Data

The Rural Electrification Information Exchange, a central bureau for the collection, analysis, and indexing of all information now available on the uses of electricity on farms, has been established by *Farm Journal*, one of the largest rural magazines in the United States.

Much experimental research and engineering work on rural electrification has been done by agricultural schools, electric utilities—private and Rural Electrification Administration companies, manufacturers, and others, but the information has remained in the files of the individual institutions, for the most part. Through the new central agency it will be made available on request to manufacturers, advertising agencies, wholesalers, farm electrical dealers, utilities, all REA agencies and co-operatives, agricultural schools, experimental stations, county agents, the press, and any others interested. This service also will be extended to farmers in an effort to help them meet individual electrification problems.

The Exchange will be under the direction of Frank E. Watts, executive assistant of the *Farm Journal* who has been specializing in the study of farm electrification for the past three years. Contributions from those having such data in their files are being solicited eagerly, and should be addressed to headquarters of the Rural Electrification Information Exchange, c/o *Farm Journal*, 420 Lexington Avenue, New York 17, N. Y.

Emergency Commercial Standard for Dial Indicators Proposed

A Proposed Commercial Standard (Emergency) for Dial Indicators, *TS*-3712, has been developed recently by the National Bureau of Standards to provide minimum essential requirements for precision dial indicators. In its present form the standard has been revised in line with composite critical opinion from the leading users, Government agencies, distributors, and manufacturers to whom it had been sent previously for review and comment. Currently it is being circulated to the trade for written acceptance, in order that it may be established as a commercial standard and be published by the Department of Commerce.

The specification covers the major essential requirements of precision dial indicators in four size groups of nominal bezel diameters, and takes up nomenclature, general requirements, detail requirements, packing, and marking. Included in the standard are four descriptive sketches of the instruments and two tables. Should the number of acceptances received warrant publication, printed copies of the standard may be obtained from the division of trade standards, National Bureau of Standards, Washington 25, D. C.

Westinghouse Purchases West Coast Radio Station. Radio station KEX, a Portland, Oreg., affiliate of the Blue Network transmitting on a frequency of 1,190 kilocycles, has been purchased by Westinghouse Radio Stations, Inc., subject to the approval of the Federal Communications Commission. According to a joint announcement from Westinghouse and from Palmer Hoyt, publisher of the Portland (Oreg.) *Oregonian*, the former owner of the station, the disposition of KEX complies with a recent FCC order limiting ownership by a single operator to one standard broadcast station in a community. Both companies were affected by the order because the *Oregonian* also owns and operates station KGW in Portland, and Westinghouse owns and operates two stations, WGL and WOWO, in Fort Wayne, Ind. Negotiations currently are in progress for the disposal of WGL by Westinghouse. When the Commission's approval has been granted, KEX will be under the general direction of Leo B. Wailes, manager of Westinghouse Radio Stations, Inc. The station has been operating since 1926.

Philco Sets Up Television Relay Transmitter Link. A New York to Philadelphia television relay transmitter link, connecting the two cities for video broadcasts, has been established by Philco Corporation, Philadelphia, Pa., and was officially dedicated on May 25, 1944. The new link, installed near Princeton, N. J., replaces previous experimental installations, and reputedly marks the beginning of the first regularly scheduled television relay system capable of providing commercial service in the United States. It is now in operation every night to make the New York programs of station WNBT available to the audience of Philco television station WPTZ in Philadelphia.

RMA Officers Elected. The Radio Manufacturers Association meeting recently in Chicago, Ill., in its third war production conference elected the following officers for the coming year:

President: R. C. Cosgrove, Cincinnati, Ohio.

Vice-presidents: E. A. Nicholas, Fort Wayne, Ind., D. T. Schultz, Newton, Mass.; Walter Evans, Baltimore, Md.; R. C. Sprague (M '40), North Adams, Mass.; T. A. White, Chicago.

Directors: H. A. Bell, Los Angeles, Calif.; R. E. Carlson, Newark, N. J.; Monte Cohen, Springfield, Mass.; S. I. Cole, New Bedford, Mass.; F. M. Folson, Camden, N. J.; G. R. Fryling, Erie, Pa.; Joseph Gerl, Chicago; F. R. Lack (M '37), New York, N. Y.; George Lewis, New York; Ernest Searing, Philadelphia, Pa.

Addition of 12 new members of RMA also was announced at the Chicago meeting. The new members are:

Consolidated Radio Products Company, Chicago; Crystal Research Laboratories, Inc., Hartford, Conn.; Electronic Laboratories, Inc., Indianapolis, Ind.; Electronic Engineering Company, Chicago; Electronic Tube Corporation, Philadelphia; General Electronics, Inc., New York; Selenium Corporation of America, Los Angeles; M. Simons and Son Company, Inc., New York; Mark Simpson Manufacturing Company, New York; Universal Microphone Company, Inglewood, Calif.; Viewtone Company, New York; Winters and Crampton Corporation, Grandville, Mich.

The Association's engineering department also arranged with the co-operation of the Society of Automotive Engineers for a series of tests of frequency modulation and other receivers on problems of automobile interference with television and FM reception. An appropriation of $5,000 was authorized for the project.

JOINT ACTIVITIES

Subcommittee of ECPD Reports on Technical-Institute Education

The subcommittee on technical institutes of the Engineers' Council for Professional Development recently presented a report for the purpose of clarifying the status and promoting the development of educational programs of the technical-institute type.

The report, which was subsequently submitted to the various engineering societies for their action, describes the scope of technical-institute education and suggests minimum requirements and recommendations as to how they may be effected. The AIEE board of directors, at its meeting on May 25, 1944, passed a resolution approving the plan for accrediting those technical schools recommended by the ECPD subcommittee.

As defined in the report, the purpose of these technical education programs is to prepare individuals possessing a high-school education or the equivalent for positions auxiliary to but not in the field of professional engineering. The work is essentially technological in nature, including virtually the entire range of engineering and technical industrial practice, and the programs verge upon skilled craftsmanship at one end of the scale and approach professional engineering practice at the other. Courses are more intensive and specific in purpose than are the collegiate engineering curricula, and in duration range from a few weeks to two or three years of full-time day-school or five or six years of evening-school attendance.

From a number of independent studies of technical-institute education, the subcommittee ascertained a need in industry for at least three times as many graduates from technical institutes as for those graduating from four-year engineering college courses. Since the output of the technical institutes falls far short of this number and since the needs of industry must be served, many engineering graduates are employed for positions requiring less expensive and less fundamental training than that provided by the degree-conferring college.

Then, too, laws governing the registration of engineers do not recognize technical-institute graduation in evaluating educational qualifications for licensure. Accrediting procedures do not include the technical institutes, and their graduates, therefore, receive no official credit for a

Future Meetings of Other Societies

American Association for the Advancement of Science. Annual meeting, September 11–16, 1944, Cleveland, Ohio.

American Society of Civil Engineers. July 16–21, 1944, Chicago, Ill.

American Society of Mechanical Engineers. Fall meeting, October 2–5, 1944, Cincinnati, Ohio; annual meeting, November 27–December 1, 1944, New York, N. Y.

Institute of the Aeronautical Sciences. Summer meeting, July 27–28, 1944, Los Angeles, Calif.; air transport meeting, September 1944, Washington, D. C.; fall meeting, November 1944, Dayton, Ohio.

Society of Motion Picture Engineers. 56th semiannual fall conference, October 16–18, 1944, New York, N. Y.

program of study that has prepared them adequately for service in numerous technical positions.

In view of these facts the committee recommended that both industry and the engineering profession act, in their own interests if for no other reason, to place technical institute education on a proper basis of quality and magnitude in the United States. Because of the diversification of programs in the various schools operating in the technical-institute field, it was suggested that each one, within stated boundaries, be judged on its own merits as to quality, and that each should be recognized and accredited in terms of its own purposes, scope, duration, and content. However, since some qualitative limits must be established within which acceptable programs must fall, the following requirements were advanced as a tentative statement of qualifications that all programs must satisfy in order to be considered.

1. Duration: not less than one academic year of full-time work, or the equivalent in part-time work.

2. Requirement for admission: high-school graduation or the equivalent.

3. Curricula: technological in nature, employing the application of physical science and the techniques of mathematics to the solution of practical problems, and comprising a prescribed sequence of related courses with a reasonable amount of elective subject matter.

4. Instruction: by accepted class, laboratory, or correspondence methods.

5. Teaching staff: qualified as to education and experience.

6. Educational institution: an organized school or a division of an institution devoted to the specific aim of education of the technical-institute type; a stable organization with adequate financial support.

7. Physical facilities: adequate for the programs offered.

The subcommittee further recommended that recognition or certification of educational programs of the technical-institute type be initiated by the ECPD, since it is the only agency of the engineering profession which has the status, backing, and public recognition necessary to insure acceptance of such certification. Power should be vested in an accrediting group, which would include representatives of the institutes themselves and of the industries served by them.

Editor's Note: As an alternative to certification by an ECPD board, an accrediting organization may be established by the institutions themselves. The National Council of Technical Schools, organized in January 1944 (see *EE, April '44, p 158* and *July '44, p 278*) is a step in this direction.

EDUCATION • • •

Minimum Standards Adopted by Council of Technical Schools

An amended Code of Minimum Standards recently was adopted by the National Council of Technical Schools. Revision of the tentative code adopted in January 1944 was based on the suggestions of eminent educators, State educational administrators, and personnel directors in industry to whom the code was submitted for comment and criticism.

After fixing the realm of the technical school between that of the trade school which teaches skills and crafts and that of the academic institution which prepares primarily for the scientific and learned professions, the approved code sets up these general qualifications for such schools:

1. Its principal courses of instruction shall be terminal rather than preparatory, intensive, practical, reflecting the best current technical practices of the field it serves.

2. Its principal courses shall either consist of one year of not less than 1,200 clock hours of class and laboratory work or have the approval of a State or Federal agency.

3. Its adequate financial resources must be evident.

4. Its manager and owners must have a satisfactory record of business integrity.

5. It must possess the confidence of the leading employers in the field it serves and maintain a satisfactory record of employment of its graduates.

6. It must be in operation five years before it is eligible for membership in the council. However newer institutions may become nonvoting members.

7. It must comply with Government requirements fo its type of school in the State in which it operates.

The code then goes on to present standards for the various grades of faculty members, the educational director, chief classroom instructor, chief laboratory instructor, and other instructors. Details of the regimen of the school—qualifications for admission, content of courses, size of classes, grading system, and building facilities—must satisfy a certain minimum. An ethical guide governing fees, advertisements, recruiting of students, and school representatives also is established by the code.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Wigwags, Zips, and Zooms

To the Editor:

I still read *Electrical Engineering* with care. My six-year-old granddaughter, "Happy," joins me to look at the "wigwags, zips, and zooms." "Happy," whose name is Anne Carolyn Burnett, uses these terms:

"wigwags" = oscillograms
"zips" = rising curves
"zooms" = falling curves
"scooters" = wheeled transformers, or tanks

"Happy" zealously and carefully goes over *Electrical Engineering* as it is received, and her questions demand intelligent answers. I suppose she is your youngest student.

DOUGLASS BURNETT (M '04)

(Retired engineer, Sparks, Md.)

The Engineering Degree

To the Editor:

Almost every time I look at the personal column in any of the engineering magazines, I note a number of engineers listed as having degrees: bachelor of science in . . . engineering, bachelor of engineering in . . . engineering, or bachelor of philosophy in . . . engineering and I often have wondered why steps are not taken to provide a means whereby engineering graduates with bachelor degrees can earn their engineering degrees without resident rematriculation.

Some institutions confer an engineering degree upon the completion of a four-year course while others (probably in the majority) require at least a year of resident graduate study as a requisite for such a degree.

Most engineering graduates find it necessary or expedient to seek employment soon after graduation and hence never find the time or the opportunity to take the additional year's work. The result is that the holders of bachelor's degrees, for the most part, are deprived of the opportunity of possessing engineering degrees no matter how much they may desire them or need the additional learning associated with them.

If the engineering schools cannot consistently confer an engineering degree with the four-year courses as now constituted, perhaps increasing the length of the scholastic year by shortening the vacation periods would permit giving the added work necessary for earning such a degree in the four-year period.

As an alternative proposition, I don't see why the various engineering schools which consider the normal four-year course insufficient for an engineering degree couldn't institute correspondence courses for their graduates, thereby making it possible for the latter to procure the higher degree.

At the present time the officials of many universities and colleges are wondering where they are going to find enough students to keep their respective institutions in the going concern class—at least for the duration and perhaps for sometime after. If they cannot find students for the undergraduate courses, I believe they have an opportunity, if they are so disposed, to keep their teaching staffs at least partially employed through the instrumentality of graduate correspondence courses.

I would be ready and willing to try such a plan even though my bachelor's degree is 37 years old.

It would be interesting to know what other "bachelor engineers" think of the graduate correspondence course.

HAROLD M. GOULD (M '42)

(Industrial engineer, Smith, Hinchman, and Corylls, Inc., Architects and Engineers, Lake City Ordnance Plant, Lake City, Mo.)

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Tool Steels. By J. P. Gill, R. S. Rose, G. A. Roberts, H. G. Johnstin, and R. B. George. American Society for Metals, Cleveland, Ohio, 1944. 577 pages, illustrated, $9^1/_4$ by 6 inches, cloth, $6. (ESL.)

The aim in this book is to set forth concisely the existing theoretical and practical information on the types of tool steel that commonly are used. A description of the manufacture of tool steel is followed by chapters on testing, the principles of heat treatment, and the effect of alloying elements on the steel. Succeeding chapters review in detail the various classes of tool steels, presenting the available data about their properties, treatment, and uses.

Oxy Acetylene Handbook. Published by Linde Air Products Company, New York 17, N. Y., 1943. 587 pages, illustrated, $9^1/_2$ by 6 inches, cloth, $1.50. (ESL.)

This is a practical basic manual intended for use in colleges, vocational schools, and shop training courses. All topics from general principles to inspection of welds and the management of shops are covered. The book supersedes the "Oxwelder's Handbook."

Modern Turbines. By L. E. Newman, A. Keller, J. M. Lyons, L. B. Wales. Edited by L. E. Newman. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, London, England, 1944. 175 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $2.50. (ESL.)

Information concerning the characteristics of steam turbines and their generators is presented for the use of engineers who are interested in the selection of equipment for a given job, but are not concerned with the details of turbine design and maintenance. The material presented appeared originally in *Power Plant Engineering*.

Theory of the Gyroscopic Compass and Its Deviations. By A. L. Rawlings. Second edition completely revised and reset. Macmillan Company, New York, N. Y., 1944. 182 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $3. (ESL.)

The theory of this compass is presented by an authority who has invented various important improvements. Included are descriptions of the Sperry, Anschütz, Arma, and other models in use today. Navigators and men concerned with the installation and maintenance of gyrocompasses, and advanced instructors in schools will find the book useful.

ASTM Standards 1943 Supplement Including Tentative Standards. Part I, Metals. 351 pages. Part II, Nonmetallic Materials—Constructional. 167 pages. Part III, Nonmetallic Materials—General. 539 pages. American Society for Testing Materials, 260 South Broad Street, Philadelphia 2, Pa., 1944. Illustrated, $9^1/_4$ by 6 inches, cloth, $3 each part. (ESL.)

These volumes bring the 1942 book of standards up to date by giving the newly adopted and revised standards and tentative standards. Included are stickers for marking the superseded standards in the 1942 books.

ASTM Standards on Rubber Products. Prepared by ASTM committee *D*-11 on rubber products; methods of testing, specifications, February 1944. American Society for Testing Materials, 260 South Broad Street, Philadelphia 2, Pa., 424 pages, illustrated, 9 by 6 inches, paper, $1.75. (ESL.)

This compilation brings together the standard and tentative methods of test and specifications pertaining to rubber products. Additions in this issue include specifications for compounds of rubber and synthetic rubber for automotive and aeronautical uses and for electric wire and cable insulation; methods of testing rubber-coated fabrics, asbestos sheet packing, and nonrigid plastics; and electrical test methods applicable to rubber products.

Alternating Current Bridge Methods. By B. Hague. Fifth edition. Sir Isaac Pitman and Sons, London, England; Pitman Publishing Corporation, New York, N. Y., 1943. 616 pages, illustrated, 9 by $5^1/_2$ inches, cloth, $8.50. (ESL.)

The purpose of this book, is to provide advanced students with an up-to-date account of methods and apparatus for a-c bridge measurements of inductance, capacitance, and effective resistance at low and telephonic frequencies. The symbolic theory of alternating currents and its application to bridge networks, the principle underlying the various instruments involved, the classification of bridge networks, and the choice of methods are discussed at length. Because of war limitations, the text is that of the fourth edition, but errors have been corrected and many notes covering later developments added. Bibliographic footnotes are frequent.

Chemistry of Cellulose. By E. Heuser. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, London, England, 1944. 660 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $7.50. (ESL.)

This book provides a compendium and critical digest of the literature on cellulose, with due consideration of the microscopic and submicroscopic structure of the cellulose fiber. The scientific aspect rather than the practical application of cellulose chemistry has been emphasized. An attempt has been made to consider all the essential literature up to October 1943.

Engineering Materials, two volumes. Volume 1—The Ferrous Metals. 369 pages, $7.50 (25*s.* abroad). Volume 2—Nonferrous and Organic Materials. 479 pages, $8.50 (30*s.* abroad). By A. W. Judge. Second edition. Pitman Publishing Corporation, New York 19, N. Y.; Sir Isaac Pitman and Sons, London, England, 1943. Illustrated 9 by $5^1/_2$ inches, cloth. (ESL.)

These two volumes form an admirable reference book for engineers, designers, constructors, and others concerned with the selection and application of engineering materials. Volume 1, on ferrous metals, presents essential information on their properties, composition, heat treatments, machining, welding, and other subjects. Volume 2, treats in similar fashion the nonferrous metals and alloys, plastics, rubber, and ceramics. The needs of aircraft and automobile engineers especially have been kept in mind.

Ferrous Metallurgy, two volumes. Volume 1—Introduction to Ferrous Metallurgy. 484 pages. Volume 2—Manufacture and Fabrication of Steel. 487 pages. By E. J. Teichert. Second edition. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1944. Illustrated, $8^1/_2$ by $5^1/_4$ inches, cloth, $4 each. (ESL.)

The two books are part of a three-volume text based upon a correspondence course given during recent years by Pennsylvania State College. Volume 1 covers the fundamental chemical and physical background and the manufacture of pig iron, cast iron, and wrought iron; volume 2, the manufacture of steel and its primary fabrication. The books give an excellent up-to-date account of practice.

General College Chemistry. By M. C. Sneed and J. L. Maynard. D. Van Nostrand Company, Inc., New York, N. Y., 1944. 861 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $3.75. (ESL.)

This text is designed for a first-year course in college chemistry in which theory and descriptive matter are balanced carefully. Historical material is introduced, and statistical and industrial materials are used freely. The work aims to give the student the necessary preliminary information for a well-rounded training in chemistry.

Graphical Solutions. By C. O. Mackey. Second edition. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, London, England, 1944. 152 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $2.50. (ESL.)

Further demand has made necessary the reprinting of this edition which appeared first in 1940. It provides a course of instruction in the construction and application of curves, diagrams, and charts for the graphical and mechanical solution of engineering problems. The treatment is elementary and practical.

Handbook of Chemistry. Compiled and edited by N. A. Lange. Fifth edition. Handbook Publishers, Sandusky, Ohio, 1944. 2,092 pages, with an appendix of mathematical tables and formulas compiled by R. S. Burington. Illustrated, 8 by $5^1/_2$ inches, fabrikoid, $6. (ESL.)

The fact that five editions of this handbook have been printed in ten years shows that it has met a demand for a convenient collection of basic data on chemistry. The new edition has been revised throughout, many tables have been extended or rewritten, and new tables have been added on flammable liquids, flame temperatures, plastics, fluorescent substances, and water for industrial use.

Illustrated Technical Dictionary. Edited by M. Newmark. Philosophical Library, 15 East 40th Street, New York, N. Y., 1944. 352 pages, illustrated, $9^1/_4$ by 6 inches, cloth, $5. (ESL.)

This dictionary defines a wide selection of terms, including many recent expressions, used in the applied sciences and in technology. Special attention is given to those generally encountered in the curricula of technical and vocational schools. Illustrations are infrequent and add little to the value of the book. The work will be useful to students and mechanics.

Industrial Electronic Control. By W. D. Cockrell. McGraw-Hill Book Company, Inc., New York N. Y., and London, England, 1944. 247 pages, illustrated, $8^1/_4$ by $5^1/_2$ inches, cloth, $2.50. (ESL.)

The purpose of this book is to supply a basic working knowledge of electronic control as a background for intelligent selling, installing, or servicing of electronic equipment. It describes, simply and nonmathematically, the fundamentals of electronic-tube operation and the basic control circuits. The book is especially for electrical engineers with no previous experience with tubes, and radio servicemen interested in electronic service work.

Iron and Steel in Britain 1870–1930. By T. H. Burnham and G. O. Hoskins. George Allen and Unwin, London, England; distributed by W. W. Norton and Company, Inc., New York, N. Y., 1943. 352 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $7.50. (ESL.)

In 1870 the British iron and steel industry held first place in the world. In 1930 it ranked fourth, both in production and exports. This volume studies the history of the industry during the interim in order to discover the factors responsible for this decline in position, and endeavors to appraise the part played by each. The book is an interesting carefully documented study. One author is a metallurgist, the other an economist.

Klystron Technical Manual. Published by the Sperry Gyroscope Company, Brooklyn 1, N. Y., 1944. 94 pages, illustrated, $9^1/_4$ by 6 inches, cloth, limited free circulation. (ESL.)

This manual describes the underlying principles of velocity-modulation tubes, rather than their applications. It brings together in simplified form the material hitherto available only in periodicals with additional experimental and descriptive information. A useful bibliography and lists of American and British patents are included.

Materials and Processes. Edited by J. F. Young. John Wiley and Sons, Inc., New York, N. Y., 1944. 628 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $5. (ESL.)

This book aims to present a broad study of the materials and manufacturing processes employed by engineering designers and thus to provide information directly useful in the selection of materials. It is intended for classroom use as well as for engineers who wish an over-all picture. The book is based on a course of lectures given in the advanced engineering program of the General Electric Company, Schenectady, N. Y.

Mathematical and Physical Principles of Engineering Analysis. By W. C. Johnson. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1944. 346 pages, illustrated, $8^1/_2$ by 5 inches, cloth, $3. (ESL.)

This book is the outgrowth of a recent course given at Princeton University. Its purpose is to present the physical and mathematical principles and methods of approach that underlie the analysis of many practical engineering problems. The viewpoint is practical and utilitarian. Emphasis is placed upon physical concepts, the use of assumptions, procedures in setting up equations, the use of mathematics as a tool in accurate quantitative reasoning, and the physical interpretation of mathematical results.

Mathematische Grundlagen der Quantenmechanik. By J. von Neumann. Dover Publications, New York 16, N. Y., 1943. 266 pages, illustrated, $9^1/_2$ by 6 inches, cloth, $3.50. (ESL.)

Neumann's, "Mathematical Bases of Quantum Mechanics," long has been esteemed by mathematicians and physicists for its thorough logical development and discussion of the subject. The present American edition has been produced, in response to demand, under license by the Alien Property Custodian. The latest German edition is reproduced with the addition of a German–English glossary.

Mechanical Properties of Metals and Alloys. (Circular of the National Bureau of Standards C447.) By J. L. Everhart and others. United States Government Printing Office, Washington, D. C. 481 pages, illustrated, 11 by 8 inches, cloth, $1.50. (ESL.)

This circular is a summary of the data available on the strength and related properties, thermal expansion, and thermal and electric conductivities of ferrous and nonferrous metals and alloys at normal, high, and low temperatures. Included are many metals and alloys which ordinarily are not considered as engineering materials. The data are presented in tables or graphs, and the source of each given.

Practical Analytic Geometry With Applications to Aircraft. By R. A. Liming. The Macmillan Company, New York, N. Y., 1944. 277 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, linen, $4.50. (ESL.)

This book is a comprehensive presentation of the application of analytic geometry to the practical mathematical definition of airplane contours and structure. Part one analyzes applications to two-dimensional space. Part two develops the application of rectangular co-ordinates to three-dimensional space. Part three applies a system of analytic analysis to curves commonly required in the lofting of streamline bodies. Although the book deals exclusively with aircraft structures, the principles developed apply equally to such related fields as the automotive and marine industries.

Abstracts on Synthetic Rubber, Part I—Articles (NRC 1136) 362 pages. Part II—Patents (NRC 1137) 200 pages. National Research Council of Canada, Ottawa, Ont., June 1943. Tables, 11 by $8^1/_2$ inches, paper, manifold, $2 each. (ESL.)

This publication provides abstracts of over 800 articles and over 700 patents dealing with synthetic rubber, as well as a list of 123 articles and books that are not abstracted. A subject index to the abstracts and an index of patentees are included.

PAMPHLETS • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Power for Mechanized War. National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y., 19 pages.

Program and Progress Report. Smaller War Plants Corporation, Washington, D. C., 58 pages.

Fifteenth Report to Congress on Lend-Lease Operations. Superintendent of Documents, United States Government Printing Office, Washington 25, D. C., 84 pages, 30 cents.

Adjustment of Production Cut-Backs. Army Service Forces, War Department, Washington, D. C., unpaged.

Dow and Magnesium. Dow Chemical Company, Midland, Mich., 76 pages.

How Quartz Crystals Are Manufactured. North American Philips Company, Inc., 100 East 42nd Street, New York 17, N. Y., 36 pages.

The Coming Battle of Materials. Dohner and Lippincott, 500 Fifth Avenue, New York 18, N. Y., unpaged.

NAM News Tax Supplement. National Association of Manufacturers, 14 West 49th Street, New York 20, N. Y., 16 pages, free to members, 10 cents per copy, $9 per hundred copies.

The Financial Situation of Industry After Two Years of War. C. C. Abbott, 23 pages, 25 cents. **Business Finances During the Critical Transition From War to Peace.** C. C. Abbott, 41 pages, 50 cents. Division of Research, Graduate School of Business Administration, Harvard University, Cambridge, Mass.